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Cordulegaster erronea Hagen *in* Selys (Tiger Spiketail) Rediscovered in Michigan (Odonata: Cordulegastridae)

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Abstract

Cordulegaster erronea Hagen *in* Selys (Tiger Spiketail) has been included on the list of Michigan Odonata based on one specimen collected in 1934. In 2016, the species was found in Kalamazoo County, Michigan. It is the least abundant *Cordulegaster* species in Michigan, and the habitat requirements in Michigan are compared with known *C. erronea* habitats in Ohio and New Jersey.

Cordulegaster (Leach, 1815) is a Holarctic genus of medium to large (~55 to 88 mm total length) dragonflies of 34 species worldwide (Schorr and Paulson 2017). The common name in North America for the family, spiketails, refers to the female ovipositor, which is elongated, heavily sclerotized, and looks much like a spike. The typical oviposition behavior is for the female to fly with vertical downward thrusts, inserting the ovipositor into the substrate at the edge of the stream. This behavior has been described as "pogoing," as in one traveling vertically and laterally with a pogo-stick. Each downward thrust into the substrate apparently results in an oviposition.

Nymphs typically inhabit first and second order woodland streams with soft substrates. Nymphs partially bury themselves in the substrate and are well-camouflaged (Dunkle 2000, Glotzhober 2006). Various studies have indicated that nymphs of different *Cordulegaster* species have distinct stream flow, substrate composition, and sediment particle size requirements (Hager et al. 2012 and references within).

Ten species of *Cordulegaster* are found in North America (Paulson and Dunkle 2016), with five confirmed for Michigan: *C. bilineata* (Carle), *C. diastatops* (Selys), *C. erronea* Hagen *in* Selys, *C. maculata* Selys, and *C. obliqua* (Say). Of these five, *C. maculata* is by far the most common and widely distributed species within the state of Michigan (Kormondy 1958, MOS 2017).

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Cordulegaster erronea is found predominantly in the eastern United States; most of the records are from the Appalachian Mountain and mid-Atlantic regions (Abbott 2006-2017). In the Great Lakes area, this species has been reported most frequently in Ohio, where it has been recorded in 14 counties (ten with voucher records, OHC 2017; four with photo or observation records, Rosche et al. 2008) and is listed as a species of special concern (ODNR 2016). Vouchers exist for one county in Illinois (ISM 2006, INHS 2017). It is considered endangered in Indiana (IGA 2014), with one voucher from 1947 (Curry 2001). *C. erronea* has been found at only one site in Ontario, discovered in 2011 (OMNR 2016), and it has not been recorded in Wisconsin (Wisconsin Odonata Survey, 2017).

Spiketails are never "easy" to find, with the exception of *C. maculata*. As of January 2017, the Michigan Odonata Survey Database (MOS 2007-2017) has adult records for 191 *C. maculata*, 32 *C. obliqua*, 9 *C. bilineata*, 29 *C. diastatops*, and 3 *C. erronea*. Nymph and exuviae records are relatively numerous (245+) for *C. maculata,* with only five for *C. obliqua*. Much of the nymph data for *C. maculata* has been the result of incidental bycatch during ichthyological research. *Cordulegaster maculata* has been found in third-order streams, and hence, found in more samples. The other species appear to have preference for small creeks and seepage runs that are much more difficult to find and sample for nymphs.

In Michigan, *C. erronea* Hagen has been an enigmatic species. Kormondy (1958) listed a *C. erronea* record for Marquette County. However, it was based upon Andrews (1929), who listed "possible" species

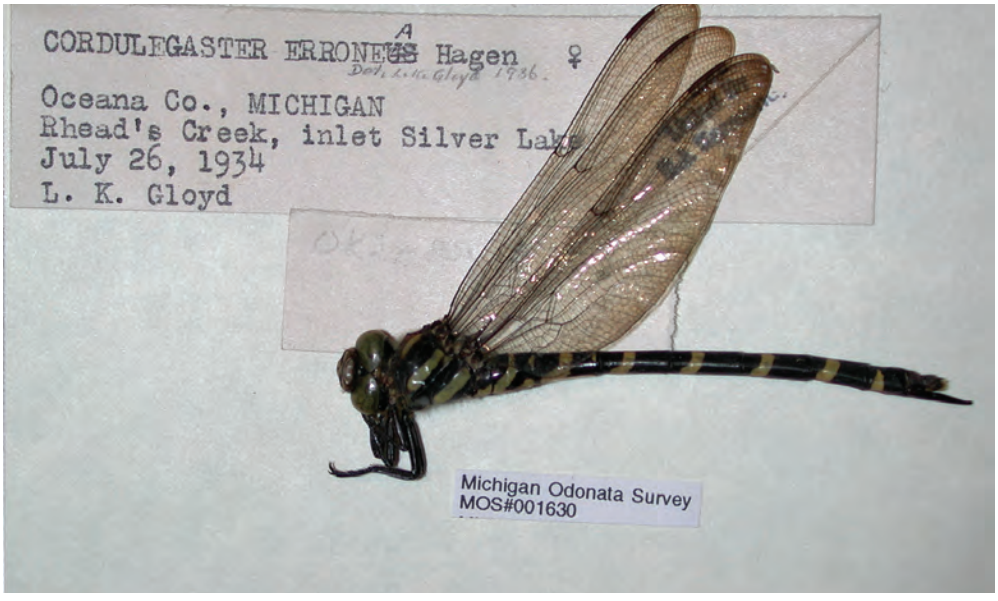

Figure 1. *Cordulegaster erronea*, female specimen collected in 1934.

to be found in the Huron Mountains. That record was refuted in O'Brien et al. (2003). The only other record for the state (Fig.1) was a female collected by Leonora Gloyd on 27 July 1934 from "Rhead's Creek inlet, to Silver Lake," Oceana County, in west-central Michigan, within 3 km of Lake Michigan (MOS001630). Given the source (Van Brink and Kiauta 1977), the veracity of the record was never in doubt but was thought to be

Figure 2. *Cordulegaster erronea* male from Fort Custer Training Center, 3 July 2016.

Figure 3. *Cordulegaster erronea* female from Fort Custer Training Center, 3 July 2016 (released after photo).

anomalous, given that it was far off the known range of the species. Prior to 2016, the nearest records to the Oceana County site were >350 km away (Abbott 2006-2017). Based on this single verified record, it is listed as a species of special concern in Michigan (MNFI 2007).

On 3 July 2016, MFO and DSO were searching for *Tachopteryx thoreyi* (Hagen), Gray Petaltail, at the Fort Custer Training Center, a military base in Kalamazoo and Calhoun counties in southwest Michigan. Mid-morning searches were conducted along a two-track adjacent to numerous seepage areas and small creeks in the Kalamazoo County portion of the base. Several attempts were made to secure spiketails, but they were too high up on branches. Farther down the road, another spiketail was observed hunting in low vegetation in a small clearing above a seepage area. The first netted specimen was a male *C. erronea* 50 m down the roadside (Fig. 2). Based upon the vivid yellow markings, we assume the previously sighted individuals were also *C. erronea*. A few meters farther down the road a second male was captured while it was perched on a small dead shrub ~1 m above the ground. At least two more *C. erronea* individuals were seen. Later, a female *C. erronea* (Fig. 3) was captured, photographed, and released on the hillside above the seeps. According to Dunkle (2000), adults perching on twigs out of reach fits well with our observations.

The habitat of the area surrounding the collection sites was Dry-Mesic Southern Forest above the sandy two-track, with Southern Hardwood Swamp at the base of the hill. Seeps are numerous, and the resulting streams flow into a Southern Wet meadow (Cohen et al. 2009). Paulson (2011) described the habitat for *C. erronea* as "small forest streams and seeps, with skunk cabbage and interrupted fern." In New Jersey, Barlow (1995) reported that this species was found only in very small (<0.3 m wide), forested, perennial cold-water streams free of substantial organic debris with a substrate of fine sand. Glotzhober (2006) studied the life history of *C. erronea* in Ohio, and densely wooded narrow and shallow first-order streams appear to be the preferred nymphal habitat. Of interest is the contrast of these habitats with southern Michigan, where hills are glacial till or old lake dunes, and not bedrock uplands like those in Ohio and New Jersey. Consequently, the flow into Michigan seeps tends to be less consistent, and may be a limiting factor in maintaining populations of seep-inhabiting species.

Groundwater seepages in the area where we found *C. erronea* need further exploration to determine the actual nymph

habitat at Fort Custer. Of concern is the potential effect of any clearing of forest from headwaters where the females oviposit and the subsequent nymphal habitat.

The comprehensive study of *C. erronea* in New Jersey by Moscowitz (2016) provides a great deal of information on the ecology and behavior of this species, which will be useful in searching for additional populations in Michigan and elsewhere.

Voucher specimens reside in the Museum of Zoology, University of Michigan. The 2016 specimen data is as follows: MICHIGAN: Kalamazoo Co., Fort Custer Reserve Training Center, S of Mott Road, along 2-track at wood's edge. 42.2938 x -85.32623, JULY 3, 2016. Mark F. O'Brien, coll. MFO-160703-1, MOS0036933; MICHIGAN: Kalamazoo Co., Fort Custer Reserve Training Center, S of Mott Road, 42.2936 x -85.3264, JULY 3, 2016, Darrin O'Brien, JAC-16-041, MOS0036997.

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New Records of Coleoptera from Wisconsin

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Abstract

Specimens of eleven different species of beetles (one of which is identified only to genus) have been collected from and are herein reported as new to Wisconsin. These species collectively occur within seven different families: Leiodidae, Latridiidae, Scirtidae, Throscidae, Corylophidae, Staphylinidae, and Dermestidae. A majority of the specimens were collected at the author's residence, either in pan traps or at UV lights; the others were taken at two nearby (township) parks.

Although Wisconsin's coleopteran fauna is large and diverse, new findings continue to reveal previously unrecorded genera and species, at least those collected from one southern county in particular (Dane County). Over the past few years, but chiefly during 2016, the author has employed a variety of collecting techniques, including (passive) usage of pan traps and UV lights, along with more traditional (and active) field techniques of examining logs, flowers, etc. Such efforts have been rewarded with the recognition of eleven different species of beetles (one of which has not been identified beyond genus level) that collectively occur within seven families: Leiodidae, Latridiidae, Scirtidae, Throscidae, Corylophidae, Staphylinidae, and Dermestidae. All species or genera herein described represent **new state records**.

Approximate coordinates of the author's residence in Oregon, Dane County, Wisconsin are as follows: 42° 54′ 14.75″, –89° 25′ 25.52″. This collecting site sits near the top of a glacial moraine and is largely surrounded by woods, whose deciduous tree species include shagbark hickory, various oaks, hackberry, boxelder, wild cherry, elm, mulberry, ash, and tulip poplar (the latter have been planted during my residence, while the former were pre-existing). A small prairie restoration adjoins the wooded area and the property itself is backed by a large agricultural field planted in row crops.

On 11 July 2015, three specimens of the round fungus beetle, *Zeadolopus egenus* (LeConte) (Leiodidae), were taken at a UV light at the author's residence. In the genus *Zeadolopus* Broun, antennae possess ten antennomeres and an uninterrupted club of four antennomeres. Antennal grooves may be found beside the eyes (Peck 2001). Currently, four species within the genus are recognized from the continental U.S. and Canada: *Z. bifoveolatus* Daffner, *Z. rubricornis* Daffner, *Z. oklahomensis* Daffner, and *Z. egenus*. The first two species on this list are known only from extreme southern Florida, while *Z. oklahomensis* has a known distribution of Alabama, Arkansas, Florida, Oklahoma, Texas, and Virginia. *Z. egenus*, by contrast, has the widest and northernmost range of the four congeners, inhabiting Alabama, the District of Columbia, Florida, Georgia, Illinois, Indiana, Kentucky, Maryland, Massachusetts, Michigan, North Carolina, South Carolina, Texas, Vermont, and Virginia, along with the provinces of Ontario and Québec, Canada (Peck and Cook 2013b). Like other members of the subfamily Leiodinae, *Zeadolopus* are believed to feed upon the spores or other tissues of various fungi, having little or no economic importance. A synonym of the genus, *Apheloplastus* Brown, was the name under which this species was listed in Downie and Arnett (1996a). Genitalic dissection is often necessary for the confirmation of species identifications within this family (Peck 2001), although that procedure was not applied in this case.

Three specimens of an unidentified species of the genus *Anogdus* LeConte (Leiodidae) were taken at a UV light at the author's residence on 11 July 2015, 29 May 2016, and 17 June 2016. *Anogdus* is a member of the *Cyrtusa* genus group, in which the mesosternum is vertical between the middle coxae (Peck and Cook 2013a). Antennae consist of eleven antennomeres, with an interrupted club of five antennomeres, in which the eighth segment is small, narrow, and disk-shaped. The genus is known only

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from the Nearctic, and a total of sixteen species are now recognized. Identifications of species require dissection of the male genitalia, which has not been performed on any of the specimens. Females of the genus are difficult or impossible to identify to species without associated males. Most species in the genus *Anogdus* were formerly included under the genus *Neocyrtusa* Brown, before its synonymy with *Anogdus* was established by Daffner (Peck and Cook 2013a). *Anogdus* belongs to the Leiodinae and shares the same feeding preferences as *Zeadolopus*.

Three specimens of the minute brown scavenger beetle, *Corticarina longipennis* (LeConte) (Latridiidae), were taken at the author's residence by three different means: on 23 April 2016 from a pan trap filled with a mixture of Pine-Sol® and water; on 29 May 2016 by beating flowers of a highbush cranberry (*Viburnum opulus trilobum*), and on 11 July 2016 at a UV light. Under the genus *Corticarina* Reitter, nineteen species were recorded from America north of Mexico (Andrews 2002) and that are generally distributed. All are considered to feed upon the conidia of various kinds of fungi. Until recently, this species had been classified within the genus *Melanophthalma* Motschulsky. But a revision of the family Latridiidae (Majka et al. 2009) has since placed this species within the genus *Corticarina*. The distinguishing feature of *C. longipennis* is the presence of a prominent denticle on each hind angle of the pronotum. Near the author's residence, this species is seemingly much less common than the more widely collected *Melanophthalma distinguenda* (Comolli), with which it might be superficially confused. Previously recorded localities of *C. longipennis* included Florida, Indiana, Iowa, Louisiana, Maine, Massachusetts, New Hampshire, New Jersey, New York, Texas, and Nova Scotia, Canada (Majka et al. 2009).

Two specimens of the marsh beetle, *Contacyphon padi* (Linnaeus) (Scirtidae), were taken at a UV light at the author's residence in 2016; the first on 6 May, and the second on 5 September (with the latter apparently signifying that another generation had been completed over the summer). Until recently, this species had been classified within the genus *Cyphon* Paykull. But a revision has since removed the synonymy of the genus *Contacyphon* Gozis to accommodate species previously classified under *Cyphon* (Zwick et al. 2013). Under *Cyphon*, thirteen species were reported from America north of Mexico (Downie and Arnett 1996b, under the family Helodidae), seven of which were known from the northeast. But that number had climbed to twenty-seven species in the same genus only six years later, as a result of taxonomic revisions (Young 2002), whose members are described as generally distributed. *C. padi* displays a clearly-defined yellowish spot on the apex of each elytron. Under the genus *Cyphon*, the species has been figured in Evans (2014). Its previously-recorded distribution stretched from the Maritime Provinces of Canada and New England to Florida and west to Indiana, with other populations occurring separately in Utah and Washington. Larvae of Scirtidae are aquatic, with some tolerance for temporary or ephemeral ponds/pools adjacent to rivers and streams, along with sphagnum bogs; some species even reproduce within treeholes or the leaf axils of bromeliads (Young 2002).

Over a span of five nights (22-27 May 2016), two different species in the genus *Aulonothroscus* Horn (Throscidae) were taken at a UV light at the author's residence. A single specimen of the first species, *A. distans* Blanchard, appeared on 22 May; three specimens of the second species, *A. convergens* Horn, were similarly taken on 26-27 May. *Aulonothroscus* is one of only three Nearctic genera in the family Throscidae and its most diverse genus, with thirteen species found generally distributed (Johnson 2002). *Aulonothroscus* is characterized by a metasternum having a deep, oblique tarsal sulcus on each side, and capitate antennae. Six species in the genus have likewise been reported from the northeast, including *A. punctatus* (Bonvouloir), *A. teretrius* Blanchard, *A. constrictor* (Say), *A. laticeps* Blanchard, *A. distans*, and *A. convergens* (Downie and Arnett 1996a). Adults are believed to be generalist feeders on pollen and mold. Members of Throscidae possess some ability to click and jump, similarly to the Elateridae and Eucnemidae (Johnson 2002).

While *A. distans* and *A. convergens* are both marked by prosternal striae (near the outer margins), those of the former taper off near the base, while those of the latter are uniform and complete. The separation of these two species is best accomplished by deeply triangular emarginations on the compound eyes of *A. convergens*, whereas only small, semicircular emarginations are present on the eyes of *A. distans*. Previously, the latter species had been reported from Massachusetts, New York, and North Carolina, while *A. convergens* was known from the District of Columbia, Florida, Louisiana, New York, North Carolina, South Carolina, and Tennessee (Downie and Arnett 1996b). Throscids most commonly occur in forested environments ranging from lowland to mid-elevations (Johnson 2002).

Two specimens of the minute fungus beetle, *Sericoderus lateralis* (Gyllenhal) (Corylophidae), were collected from differ-

ent localities in 2016; in the first case, a specimen was beaten from blossoms of a Russian olive tree (*Elaeagnus angustifolia*) at Oregon's Bicentennial Park on 19 May (approximate coordinates of park's entrance: 42° 53′ 58.6″, –89° 22′ 27.3″), while the second specimen was taken at a UV light at the author's residence on 5 July. Within the genus *Sericoderus* Stephens, five species are recognized from America north of Mexico, all of which are considered widely distributed. As members of the family Corylophidae, both larvae and adults are consumers of a variety of fungal spores (Bowestead and Leschen 2002).

Three species of *Sericoderus* are known from the northeast: *S. subtilis* LeConte, *S. obscurus* LeConte, and *S. lateralis* (Downie and Arnett 1996b). The genus is characterized by an oval body form having the elytra tapering significantly behind and the strongly bisinuate hind margin of the pronotum, whose hind angles are prolonged backwards. In the case of *S. lateralis*, the reddish to yellowish pronotum has a nebulous dark spot near the anterior margin; the elytra are dark and truncated. The species is figured in Evans (2014). The distribution of *S. lateralis* is described as "cosmopolitan," with records from the provinces of British Columbia, Manitoba, Ontario and Québec, Canada; in the U.S., it has been previously taken in Florida, Indiana, Massachusetts, Michigan, New York, Oregon, and Washington (Downie and Arnett 1996b).

A single specimen of another corylophid, *Arthrolips misellus* (LeConte), was taken at a UV light at the author's residence on 10 August 2016. Within the genus *Arthrolips* Wollaston, eight species are identified from America north of Mexico (Bowestead and Leschen 2002), whose distribution is primarily southern and western. Of these, only *A. misellus* had been reported from the northeast, from Massachusetts and Pennsylvania to Virginia (Downie and Arnett 1996b, Evans 2014). The species is figured by the latter author. This finding appears to represent the first Midwestern record of the species and seemingly marks its westernmost appearance beyond the Atlantic seaboard. In the genus *Arthrolips*, the hind margin of the pronotum extends straight across. *A. misellus* possesses a reddish-to yellowish pronotum and dark, truncated elytra. But the congener species *A. decolor* (LeConte), which has been collected in Iowa, is a uniform pale yellowish-brown (http://bugguide.net/node/view/262787). Larvae and adults of both species presumably consume fungal spores.

A single specimen of the rove beetle, *Aleodorus bilobatus* (Say) (Staphylinidae) was taken in a pan trap filled with a mixture of Pine-Sol® and water on 18 April 2016 at the author's residence. In the genus *Aleodorus* Say, four widely distributed species have been recorded from America north of Mexico, while one species has been described from Mexico itself. Like most other staphylinids, they are presumably predaceous or omnivorous, feeding upon fungi or decaying organic matter. The genus is characterized by the mesosternum occurring on a level ventral to the metasternum, and the mesosternal process is short and acute, not extending between the middle coxal cavities (Newton et al. 2001). In *Aleodorus*, the pronotum is strongly constricted basally, and has a deep, longitudinal sulcus. Within the northeast, only two species of *Aleodorus* have been taken: *A. scutellaris* (LeConte) and *A. bilobatus*. The latter has the wider distribution, being known from the Province of Ontario, Canada, along with the U.S. states of Connecticut, Georgia, Illinois, Indiana, Kentucky, Massachusetts, Maryland, Michigan, New Jersey, New York, North Carolina, Pennsylvania, Virginia, and West Virginia (Downie and Arnett 1996a). *A. bilobatus* may be distinguished from *A. scutellaris* by the presence of a broad, smooth median channel on the scutellum, which is absent from the latter. Habitus drawings of *A. bilobatus* are shown in Downie and Arnett (1996a, Fig. 27.25), and in Newton et al. (2001, Fig. 273.22).

Two specimens of another rove beetle, *Ocypus nitens* (Schrank) (Staphylinidae), were captured separately in 2016; the first, on basement carpeting of the author's residence, 8 October, while a second specimen was found outdoors crawling on a paved asphalt trail at the Oregon Town Park, 1 November (approximate coordinates of the park's entrance: 42° 54' 7.7", –89° 25' 15.6"). The first case provides confirmation that the species often wanders into dwellings and whose lifestyle is strongly synanthropic (Brunke et al. 2011). In the second (outdoor) case, it should be noted that the asphalt trail had only been installed earlier that summer. The beetle's appearance perhaps reflected the considerable ground disturbance associated with construction of the trail.

In the genus *Ocypus* Leach, four adventive European species have been reported from America north of Mexico; all are predaceous. Yet, two of those species have only been recorded from western or southwestern localities: *O. aeneocephalus* (DeGeer) was originally discovered at Vancouver, British Columbia and has not been taken outside of that province; *O. olens* (Müller), also known as the Devil's Coach Horse (Eaton and Kaufman 2007), was first discovered in southern California and has subsequently spread as far north as Washington and

eastward into Arizona (Newton et al. 2001). Two other species, *O. brunnipes* (Fabricius) and *O. nitens*, were previously recorded only from New Hampshire and Massachusetts, although that distribution has subsequently expanded to include Maine, Rhode Island, and New York. While bodies of the latter two species are both black, *O. brunnipes* has almost entirely brownish legs (femora, tibiae, and tarsi), whereas the legs of *O. nitens* are black with the exception of brownish tarsi (Brunke et al. 2011). The latter species is also figured in Evans (2014). As far as is known, these specimens of *O. nitens* from Wisconsin represent the westernmost occurrence of that species within the U.S. to date. By what means it has suddenly appeared in the Midwest cannot be answered, unless it has simply remained undetected until now.

Finally, two specimens of the dermestid beetle, *Dermestes nidum* Arrow (Dermestidae), were collected by two means and from separate places. In the first case, an adult was captured at Oregon's Bicentennial Park on 11 April 2003; in the second case, an adult was taken at a UV light at the author's residence on 6 May 2013. In the genus *Dermestes* Linnaeus, fifteen species are represented from America north of Mexico. They are characterized by the lack of a median ocellus while the procoxae are large and contiguous at their apices (Kingsolver 2002). As scavengers, they feed upon dried animal and plant remains, e.g., carcasses, that are rich in protein. The only regional study of Dermestidae in Wisconsin (Bayer et al. 1972) reported the occurrence of eight species in the genus *Dermestes*: *D. ater* DeGeer, *D. caninus* Germar, *D. fasciatus* LeConte, *D. frischi* Kugelmann, *D. lardarius* Linnaeus, *D. maculatus* DeGeer, *D. peruvianus* Castelnau, and *D. talpinus* Mannerheim. Specimens of *D. nidum* are elongate-oval and have a uniform dark reddish brown coloration, including appendages. This species has been previously reported from California, Florida, Georgia, Indiana, New Mexico (?), New York, Ohio, Oklahoma, Texas, and West Virginia (Beal 2003).

Apart from the newer specimen of *D. nidum*, which was donated as a voucher to the Wisconsin Insect Research Collection (WIRC), all specimens described herein are currently held in the author's personal collection (JDMC).

Discussion

The predominance of these new records within Wisconsin, especially during 2016, naturally poses the question of causation. One of the leading factors *might* have been the unusually mild, el Niño winter that preceded the collecting season (although locally it was more moderate than the corresponding winter of 2012). Here, we might speculate that such warmer temperatures enabled a somewhat larger number of coleopteran fauna to survive (over those experiencing average, harsher conditions), and which raised their numbers above some kind of 'threshold' to reach a higher detectable (or 'collectable') level than would otherwise occur. In a few cases, however, the pan traps themselves almost certainly made a difference, as this was the first year in which the author employed them. Undoubtedly, luck/contingency also played an important role.

Acknowledgments

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Species and Life Stages of Odonata Nymphs Sampled with Large Drift Nets in Two Wisconsin rivers

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Abstract

Because relatively few nymphs of Odonata are caught in most drift studies, they have been inconsistently reported and little is known about the species and life stages that are predisposed to drift. We used large drift nets with relatively coarse mesh sizes (1500 μm) to sample late-instar odonate nymphs in two large rivers in Wisconsin. These nets were presumed to have advantages over smaller, conventional aquatic insect drift nets, including the capability to sample greater water volumes more quickly, sampling for longer periods of time before nets become clogged with debris, and a reduced likelihood of large, active insects escaping from the nets. Nymphs of 14 species of Odonata in five families were caught, but drift densities were low (0.042 m^{-3} overall; $\leq$0.007 m^{-3} for most species) and final instar nymphs (F-0) were collected less frequently than younger nymphs (F-1 through F$\leq$4). Gomphidae comprised 83% of the nymphs collected, and three species of *Ophiogomphus* comprised 78% of the total in the St. Croix River. *Ophiogomphus howei* Bromley was the most commonly sampled species (drift density of 0.026 m^{-3}), with at least five instars collected.

Larval and nymphal forms of many aquatic insects drift downstream with the current in considerable numbers in an ecologically important phenomenon known as drift (Waters 1972, Muller 1974, Allan 1995). A number of categories of drift have been proposed, and some ecological reasons for drift behavior have been identified. Drift can have active or passive modes, and behavioral, diel, seasonal, and taxonomic attributes (reviewed by Brittain and Eikeland 1988). Odonates, however, have generally been thought to have a low predisposition to drift (e.g. Koetsier and Bryan 1995, Corbet 1999 [pp. 15, 394], Ward and Mill 2007) and the list of odonate species known to drift is likely only a small proportion of those that do so. It has been suggested that drift of odonates is largely passive and "accidental", occurring as a result of dislodgement by high flows (Leipelt 2005, Ward and Mill 2007), as opposed to the active drifting shown by some Ephemeroptera, Trichoptera, and Diptera. Benke et al. (1986) suggested that clinging animals such as odonates are more easily dislodged from substrates by the current than those with retreats or those that are attached to the substrate. Odonata nymphs have frequently been overlooked and inconsistently reported in drift studies, probably because the numbers collected have been small (e.g. Elliot 1967, Bishop and Hynes 1969, Cowell and Carew 1976, Winnell and Jude 1991, Brewin and Ormerod 1994, March et al. 2003, Bass 2004), and because part-grown nymphs of some species are difficult to identify.

Little is known about the life stages of Odonata that are predisposed to drift, but recently developed methodology (Tennessen 2016) has now facilitated the determination of the instar number of Anisoptera nymphs. Waters (1972) noted that the greatest drift of many aquatic insect species occurs in the younger life stages; this might be true for Odonata as well. For example, the small size of Zygoptera nymphs reported by Bishop and Hynes (1969) suggested that they were not full grown (< F-0).

The drift nets commonly used to sample aquatic insect drift tend to have net openings $\leq$0.09 m^{-2}, lengths of ca. 80–140 cm, and relatively fine mesh sizes of 250–500 μm (Anderwald et al. 1991). While nets of this size are appropriate for the great majority of aquatic insect taxa, they could be considered inappropriately small when larger aquatic

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insects such as nymphs of some odonate species are targeted. Sampling large volumes of water has been proposed as a means for providing information about downstream movement patterns of a variety of aquatic organisms, information that is difficult to obtain because of low drift densities (DuBois and Rackouski 1992, DuBois and Stoll 1995). Use of nets larger than those typically used to sample insect drift, including greater net lengths and larger mouth openings and mesh sizes, should have a number of advantages for sampling larger insects that occur infrequently in the drift. These advantages include the capability of sampling greater volumes of water per unit time, sampling for longer periods of time before nets become clogged with debris, sampling greater depth ranges of the water column, and a reduced likelihood that large, active insects could escape by crawling or swimming out of the net during the sampling period. We therefore used drift nets larger than those typically employed, to sample nymphs of Odonata in two large rivers in northern Wisconsin. One of the rivers, the St. Croix River in Burnett County, was sampled at a section where high densities of clubtail (Gomphidae) exuviae had previously been found (DuBois 2015). In so doing, we sought to gain increased insight into the species and life stages of nymphs of Odonata predisposed to drift in these rivers.

Materials and Methods

Large drift nets were used to sample nymphs of Odonata in the Wisconsin waters of two rivers near the border of Wisconsin and Minnesota. The 288-km St. Louis River drains a watershed of 10,093 km^{-2} and is the largest U. S. tributary to Lake Superior. The study area was located immediately downstream of State Highway 23 bridge, on the south side of the river (N46.6579; W92.2837) in Douglas County. This area was in the upper estuary of the river where it approaches the western end of Lake Superior, and river width at the sampling site was ca. 200 m. The St. Croix River is a 272-km tributary of the Mississippi River that is listed as a National Scenic Riverway under the protection of the National Park Service. The study area (known as Riverside Landing) was located immediately downstream of State Highway 35 bridge, on the north side of the river (N46.0750; W92.2485) in Burnett County, and river width at the sampling site was ca. 65 m.

We used two large drift nets designed to sample the fry of lake sturgeon (*Acipenser fulvescens*) with D-shaped openings 75 cm wide x 54 cm high and opening areas of ca. 0.30 m^{-2} (Research Nets, Inc., P. O. Box 249, Bothell, Washington). The nets were made of 1500 μm mesh netting and were 3.5 m in length. Mesh of this size was anticipated to retain Anisoptera nymphs of at least the last four instars and Zygoptera nymphs of F-0 and F-1. The terminal collection cups were 10.5 cm x 30 cm. Nets were tied with nylon ropes to anchors placed 4 m upstream of each net. Anchors were dropped onto the substrate several minutes before the nets were set to ensure that odonates retained by the nets did not result from the upstream substrate being disturbed. In each river, one net was placed ca. 4 m from shore and the other ca. 7 m from shore. Water depths at the points of sampling in the St. Louis River ranged from 75–150 cm. In the St. Croix River, water depths were 60 cm for the nearshore net and 70 cm for the more distant net. Both nets were completely submersed for the duration of all samples. Because the usual time of maximum insect drift is just after complete darkness (Waters 1972, Wiley and Kohler 1984, Allan and Russek 1985, Benke et al. 1986, Brittain and Eikeland 1988), drift samples were taken post-dusk. On each date, the two nets were set at ca. 9 pm CST and three samples were taken per net, with 3-5 min breaks between samples to empty the collection cups. Current velocity (m s^{-1}) was measured once at the sampling site of each river, 4 m from shore, by averaging repeated measurements of the time taken for a float to travel 30.5 m, centered at the point of sampling.

In the St. Louis River, drift was sampled six times (three times each per net) on six evenings in spring 2007 (29 and 31 May; 4, 7, 12 and 14 June). Current velocity as measured on 29 May at the sampling site was 0.91 m s^{-1}. Each net sampled drift for an approximate average of 2.5 hr each evening (ca. 45 min per sample), but exact sampling times were not recorded for all samples. Numbers of drifting odonate nymphs were tallied for each sample. Samples were obtained in water temperatures ranging from 15.5 C to 22 C, and river discharges ranging from 73.6 m^3 s^{-1} to 116.0 m^3 s^{-1} (http://waterdata.usgs.gov/nwis/uv?04024000; accessed 7 October 2016). The median daily discharges for this site (109-yr dataset) were 110 m^3 s^{-1} for 29 May and 105 m^3 s^{-1} for 14 June (website above).

In the St. Croix River, three 30-min samples were taken with each net between 9 pm and 11:00 pm CST on 20 May 2008. Drift densities were estimated by dividing the number of odonate nymphs in a sample by the water volume sampled. Water volumes sampled (m^{-3}) were calculated by multiplying current velocity, the size of the submerged net opening area, and sampling time. Current velocity was 0.98 m s^{-1}; volumetric flow rate was 0.294 m^3 s^{-1} per net. Therefore, each

30-min sampling period strained a water volume of 529 m^{-3} (total water volume sampled during the evening = 3,175 m^{-3}). Samples were taken at a water temperature of 15 C, and river discharge was 39.6 m^3 s^{-1} (http://waterdata.usgs.gov/usa/nwis/uv?05333500). The median daily discharge for this site (103-yr dataset) was 46 m^3 s^{-1} for 28 May (website above). Weather was clear with no moon visible until after sampling had been completed.

Odonata nymphs were preserved in jars of 80% ethanol. Determinations were usually made to species using dichotomous keys and also by comparison with reared exuviae (F-0 to F-3 or F-4 for most species). Most nymphs of all stages collected possessed distinguishing characters in sufficient states of development to identify them to species, except that we did not attempt to separate nymphs of *Hylogomphus*, none of which were full grown. Instars were determined by relating the length of the hind wing sheaths (WL) to the maximum width of the head (HW) (Tennessen 2016). Ratio ranges for instars F-0 through F-4 are usually discretely grouped with little overlap for most North American families of Anisoptera (Tennessen 2016). Nymphs in instar F-4 and younger were grouped in one category. North American Zygoptera also exhibit gradually increasing WL to HW ratios as they molt into increasingly late instars, but the details of the ratios have not been worked out. Instars of older nymphs of Zygoptera (F-0 and F-1) were determined by supposition based on WL and total length of the nymph relative to those dimensions of reared exuviae. Voucher specimens are housed in the Odonata Collection of the Wisconsin Department of Natural Resources at the address of the senior author.

Results

St. Louis River—Forty (40) nymphs representing six species of Odonata were collected during a total of ca. 21 hrs of sampling (Table 1). Thus, about two nymphs were retained per net-hour. *Argia moesta* (Hagen), *Macromia illinoiensis* Walsh, and *Gomphurus fraternus* (Say) were the species most commonly collected. Instars of Odonata from F-0 to F≤4 were all represented, with F≤4 being the largest category. No F-0 Anisoptera were collected and 40% of

Table 1. Numbers of drifting Odonata by instar in the St. Louis (left of slash) and St. Croix rivers (right of slash), and drift densities (all instars pooled) in the St. Croix River, Wisconsin (dash = no data).

	Instar				Instar	St. Croix River drift densities	
Species	F-0	F-1	F-2	F-3	F≤4	Totals	(# m^{-3})
Coenagrionidae							
Argia moesta (Hagen)	7/1	5/-	-/-	-/-	2/-	14/1	<0.001
Enallagma exsulans (Hagen)	2/1	-/1	-/-	-/-	1/-	3/2	<0.001
Ischnura verticalis (Say)	-/1	-/-	-/-	-/-	-/-	-/1	<0.001
Aeshnidae							
Basiaeschna janata (Say)	-/-	-/-	-/-	1/-	-/-	1/-	-
Gomphidae							
Dromogomphus spinosus Selys	-/-	-/-	1/-	-/1	3/-	4/1	<0.001
Gomphurus fraternus (Say)	-/-	-/-	1/-	1/-	6/-	8/-	-
Gomphurus ventricosus (Walsh)	-/1	-/1	-/-	-/1	-/2	-/5	0.002
Hylogomphus spp.*	-/-	-/1	-/3	-/3	-/6	-/13	0.004
Ophiogomphus anomalus Harvey	-/-	-/-	-/-	-/-	-/1	-/1	<0.001
O. howei Bromley	-/13	-/12	-/22	-/17	-/16	-/80	0.026
O. rupinsulensis (Walsh)	-/2	-/-	-/4	-/4	-/12	-/22	0.007
Progomphus obscurus (Rambur)	-/-	-/-	-/-	-/1	-/-	-/1	<0.001
Cordulegastridae							
Cordulegaster maculata Selys	-/-	-/-	-/-	-/-	-/1	-/1	<0.001
Macromiidae							
Macromia illinoiensis Walsh	-/1	2/-	1/1	3/-	4/2	10/4	0.001
Totals	9/20	7/15	3/30	5/27	16/40	40/132	0.042

**Hylogomphus adelphus* (Selys) and *H. viridifrons* (Hine) were both common in the reach sampled.

nymphs of that suborder were in the F≤4 category (Table 1). The two nets sampled a water volume of ca. 20,640 m^{-3} during six evenings, yielding a mean of one odonate nymph per 516 m^{-3} of water sampled and a mean drift density of 0.002 m^{-3}.

St. Croix River—Odonate nymphs totaling 132 individuals of 12 species were collected during six hours of sampling (Table 1). Each net caught 66 nymphs, yielding a mean of 22 nymphs per net-hour. Five species of Gomphidae comprised 93% of the total, and three species of *Ophiogomphus* made up 80%. *Ophiogomphus howei* Bromley was the most commonly collected species, comprising 61% of the Odonata drift total with a mean drift density of 0.026 m^{-3}. Final instar nymphs were collected less often than earlier instars, accounting for only 15% of the total (16% in the case of *O. howei*). The last five instars of *O. howei* were all found in the drift, but the instar with the greatest number of drifting nymphs was F-2 (Table 1). The total volume of water sampled by the two nets was 3,175 m^{-3}, with a mean of one Odonata nymph per 24 m^{-3} of water sampled (a mean drift density of 0.042 m^{-3}).

Discussion

Compared with standard aquatic insect drift nets available for purchase from biological supply retailers, the large drift nets we used had mesh sizes several times larger, about 20 times greater net lengths, and more than 3 times the combined area of the openings. These larger dimensions should have conferred advantages for capturing later instar nymphs of Odonata, including much more water volume sampled per unit time, less back pressure, longer sampling times before the nets become clogged with plant debris, and less-frequent escape of nymphs once inside the net. Although we did not make comparative measurements of these aspects of net functionality (larger vs. smaller nets), the large nets we used did perform as anticipated in straining large volumes of water without clogging with debris. A mesh size of 1500 μm appeared to be a reasonable compromise for sampling late-instar nymphs of Odonata. Small nymphs might have passed through mesh of this size, but early instar nymphs (F-5 or younger) are usually difficult to identify and are therefore less often useful. Conventional aquatic insect drift nets with mesh sizes ranging from 250–500 μm would retain earlier instar nymphs more reliably than the nets we used, but they would also clog with vegetative debris more quickly and would be subject to greater water resistance. If concerns arise about larger-mesh nets failing to retain early instar nymphs of Odonata, using multiple net sets incorporating different opening and mesh sizes could improve representation of large and small taxa groups.

Comparing our relatively low Odonata drift densities with those reported in other studies is inconclusive in all but a most general sense because relatively few studies have reported drift densities of gomphids, and those few have provided disparate results. Obi and Conner (1986) reported a low mean drift density of 0.07 nymphs per 100 m^{-3} of *Gomphus* sp. in the lower Mississippi River in Louisiana. Pendergrass (2006) found odonates, including five genera of Gomphidae (not including *Ophiogomphus* however), to be common in the benthos of the Blanco River, Texas, but odonates were absent from the drift. Conversely, Cloud (1973) reported a relatively high mean drift density of 5.5 nymphs per 100 m^{-3} of *Ophiogomphus* spp. for six semi-monthly samples from the Brazos River, Texas. DuBois and Smith (2016) used a marking study in a small river in Wisconsin to assess the downstream movement of F-0 nymphs of a robust population of *Ophiogomphus rupinsulensis* (Walsh) from fall through spring of the following year. They found that nearly all marked nymphs moved some distance downstream, in a few cases 75 m or more, but most nymphs (79%) moved less than 30 m. Kennedy and Benfield (1979) did not provide drift densities for the New River, Virginia, but noted that nine species of Odonata were collected in the drift (of 22 species of Odonata known to occur in the river), among them *Ophiogomphus aspersus* Morse and *O. howei*. In a particularly intriguing study, Arai (1993) noted that nymphs of *Stylogomphus suzukii* (Matsumura in Oguma) inhabited upper reaches of mountain streams in Japan, but that exuviae were found along lower reaches; these findings led him to surmise that the nymphs somehow moved downstream. In synthesis, these results raise the possibility that species of *Ophiogomphus*, and perhaps *Stylogomphus* as well, might have relatively high propensities to drift. However, despite the presumed advantages of the large nets we used, the odonate drift densities we measured, even in a gomphid-rich section of the St. Croix River, were not especially high, and were indeed much lower than those Cloud (1973) reported for *Ophiogomphus*.

Although drift densities were only approximate in the St. Louis River because sampling times on that river were approximated, it is clear that numbers of drifting odonates there were only about one tenth of those in the St. Croix River, despite samples being taken at the same time of season and day. This difference could be due to differences in the productivity of the two rivers,

reach-scale differences in habitat, or species-specific differences in propensity to drift. The highest densities of gomphid exuviae found along 10 rivers in northern Wisconsin by DuBois (2015) were in the same section of the St. Croix River sampled in this study. Further, the St. Croix River is rich in species of *Ophiogomphus*, a genus which may have a relatively high propensity to drift, whereas *Ophiogomphus* nymphs were not collected in the St. Louis River. It was not unexpected that *O. howei* was the dominant species in the St. Croix River drift (F-0 nymphs of that species comprised 84% of the drifting F-0 gomphids collected): this species also made up ca. 2/3 of the total number of gomphid exuviae collected on shore in June 2008 within just a few meters of our drift sampling point (DuBois 2015, Table 3, Trial #5).

Drift-netting is not commonly practiced specifically for the collection of odonates, and our results concord with many other studies in showing that large volumes of water must be strained to capture a relatively small number of specimens. The fact that most of the nymphs we collected drifting were not in their final instar further compromises the usefulness of drift sampling for odonates because partly-grown nymphs can be difficult to identify, even at the genus level. However, in circumstances in which sampling for odonates using other methods is impractical, drift-net collections can supply useful information about species presence. Pringle and Ramirez (1998) noted that drift sampling in biodiversity assessment is potentially useful because it provides integrated samples of various habitats (advantageous if the habitats of some species are unknown or difficult to sample), it is relatively 'clean' in that target organisms are not mixed with substrate materials, and it is non-destructive of benthic habitats. Thus, drift sampling can be seen as a complementary tool in the assessment of aquatic invertebrate assemblages (Calisto and Goulart 2005).

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Notes on the Nests of *Augochloropsis metallica fulgida* and *Megachile mucida* in Central Michigan (Hymenoptera: Halictidae, Megachilidae)

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Abstract

Notes on the nesting biology of two ground-nesting bee species are provided from Central Michigan. A single nest of *Augochloropsis metallica* (Fabricius) *fulgida* (Smith) was excavated on 12 July 2014 in Shiawassee County. There were two female nest inhabitants. Examination of mandibular wear, wing wear and ovarial development suggests one female was acting as a worker caste. Also, a nesting aggregation of *Megachile mucida* Cresson was observed in Ingham County. Information on nest architecture and cell construction is based on excavations of several nests during 7–15 June 2014. *Megachile mucida* is recorded as a new host species for the cleptoparasite *Coelioxys sodalis* Cresson. This is the first record of *M. mucida* in Michigan, additional collection records of this species in Michigan are also reported.

Introduction

The bee families Halictidae and Megachilidae are remarkable for their varied nesting habits (Medler and Lussenhop 1968; Michener 1974, 2007; Yanega 1997; Litman et al. 2011; Gibbs et al. 2012), however basic natural history remains limited for many species. This is problematic for taxa where social behavior or nesting biology varies within a genus, which is commonplace among halictid and megachilid bees. Since there is a lack of published information on many bee species, even brief notes can be informative.

The New World tribe Augochlorini (Hymenoptera: Halictidae) is most diverse in the Neotropical region (Michener 2007), but four species in three genera are known to occur in Michigan: *Augochlora pura* (Say), *Augochlorella aurata* (Smith), *Augochlorella persimilis* (Viereck), and *Augochloropsis metallica* (Fabricius) *fulgida* (Smith). The nests of *A. pura* and both *Augochlorella* species have been studied in detail (Ordway 1966, Stockhammer 1966, Packer et al. 1989, Mueller 1996). *Augochlora pura* is a solitary, wood-nester (Stockhammer 1966) commonly found in rotting logs in the eastern United States, including southern Michigan. *Augochlorella aurata* and *A. persimilis* form eusocial, occasionally semisocial or solitary, underground-nests (Ordway 1966, Packer et al. 1989, Packer 1990, Mueller 1996). There are no published studies of the nests of *A. metallica*. Some data on laboratory colonies are mentioned by Eickwort and Sakagami (1979) in reference to the subgenus *A.* (*Paraugochloropsis*), but specific details for *A. metallica* are not provided. Five species of Neotropical *Augochloropsis* from Brazil and Costa Rica have been studied in detail (Michener and Lange 1959, Michener and Seabra 1959, Gimenes et al. 1991, Coelho 2002) and a broad spectrum of social behaviors were documented, including solitary, communal, semisocial, and eusocial nesting. The Nearctic species *A. sumptuosa* (Smith) was studied in both New Jersey (Smith 1901) and Kansas (Michener and Lange 1959), using the specific epithet *humeralis* (Patton), and found to be communal or semisocial.

Bees in the genus *Megachile* (Megachilidae: Megachilini) are commonly referred to as leaf-cutter bees for their use of masticated or cut leaves in cell construction (Medler and Lussenhop 1968, Litman et al. 2011), but other materials may also be used instead, including plant resins (Krombein 1967, Medler and Lussenhop 1968, Litman et al. 2011, O'Neill and O'Neill 2016). Leaf-cutter bees nest in both pre-existing cavities (Fye 1965, Krombein 1967) and underground burrows (Krombein 1953, Eickwort et al. 1981, Sheffield et al. 2011). Members of the subgenus *M.* (*Xanthosarus*), which includes *Megachile mucida* Cresson, nest in both underground burrows (Graenicher 1905, Sladen 1918, Hobbs and Lilly 1954, Cane et al. 1996) and

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logs or stems (Stephen 1956, Medler and Lussenhop 1968). Two Michigan species, *M. gemula* Cresson and *M. melanophaea* Smith, are strikingly similar morphologically to *M. mucida*, but differ in their nesting biology (Graenicher 1905, Fye 1965, Medler and Lussenhop 1968). *Megachile gemula* nests in hollow twigs or poplar logs (Fye 1965) and *M. melanophaea* nests in the ground (Graenicher 1905). Given the differences between close relatives, it is worth documenting the nesting biology of *M. mucida.*

The objective of this paper is to provide brief notes on the nests of *Augochloropsis* (*Paraugochloropsis*) *metallica fulgida* and *Megachile* (*Xanthosarus*) *mucida*, since published information on these species is otherwise lacking. The descriptions below are intended to fill gaps in knowledge of bee natural history and to demonstrate the potential value of such observations even when not conducted as part of a detailed scientific study.

Methods

A single nest of *A. m. fulgida* was discovered on 12 July 2014 while collecting bees in a small clearing at Rose Lake Wildlife Area, Shiawassee County (N42.8075, W84.363). The nest entrance was completely obscured from above by a leaf (Figs. 1A, 1B), and the nest was only recognized by seeing a returning female. Flowers at the site included *Monarda fistulosa* L. and *Asclepias tuberosa* L. No other *Augochloropsis* nests were found in the vicinity, although *M. texana* Cresson was seen nesting in the same clearing. The nest was excavated by spraying dry plaster of plaster down the entrance. A grass stem was also carefully slid down into the burrow to help track the path of the nest. A hole approximately 20 cm deep was dug to one side of the entrance. The soil was carefully scraped away from the side until the burrow and cell cluster were found. Two or three cells were opened immediately to appease my curiosity or the immatures were damaged during removal of the cells. The remainder of the cells were returned to the lab and individuals reared to adulthood. Dissections of the metasomata were made from adult females active in the nest and two lab reared females. The metasomata from pinned specimens were rehydrated in water overnight before dissection. Mandibles and wings were assessed for wear using the newly emerged females as a standard for comparison.

Records of *M. mucida* for Michigan were based on my own collections, deposited at the J. B. Wallis / R. E. Roughley Museum of Entomology (JBWM), and re-examination of material in the A.J. Cook Arthropod Research Collection (MSUC). Since *M. mucida* had never before been recorded in Michigan and because it could be easily mistaken for either *M. gemula* or *M. melanophaea*, historical collections of these two latter species were re-examined to verify their determinations. Identifications of *M. mucida* and *Coelioxys sodalis* Cresson were based on information from published keys (Mitchell 1935, 1962; Baker 1975) and comparison to identified material in the MSUC.

A nesting aggregation was discovered on a former farm lane currently used as a walking path at Fenner Nature Center, Ingham County (N42.7089, W84.5226). The site was on a slight south-facing slope, with sandy soil and sparse weedy vegetation (e.g., Brassicaceae and Oxalidaceae). Observations and nest excavations were made haphazardly over the course of four weeks at the Fenner Nature Center. Eight nests were excavated using methods similar to those above. Nests were selected based on female activity allowing association of the bee to the nest contents. Completed cells were returned to the lab to be reared. Cells were stored in an unheated building during the winter before being brought back to the lab in spring and kept at room temperature.

Results

Augochloropsis (*Paraugochloropsis*) *metallica fulgida*

A nest of *A. m. fulgida* was discovered and excavated on 12 July 2014. The burrow extended nearly straight down from the horizontal surface for approximately 15 cm before taking a 90 degree turn towards the adjacent cluster of vertical cells (Figs. 1C, 1D). The nest architecture fits the category IbLV (Sakagami and Michener 1962, Eickwort and Sakagami 1979). The cluster of approximately 15 cells was damaged slightly during the excavation, and was removed leaving a small fist-sized space in the soil (Fig. 1D). Two adult females were found inside the nest. These were captured for later dissection. Emergences began on the 17th of July and continued every 1–2 days and was over by mid-August. In total, 9 males and 4 females were reared from the nest in the following order: 1 ♂ (17 Jul.), 1 ♂ (19 Jul.), 1 ♂ (21 Jul.), 1 ♂ (24 Jul.), 1 ♂ (25 Jul.), 1 ♂and 1 ♀ (26–27 Jul.), 1 ♂ (28 Jul.), 1 ♀ (29 Jul.), 1 ♀ (31 Jul.), and 2 ♂♂ and 1 ♀ (2–12 Aug.). The last three individuals, two males and one female, emerged between the 2–12 August, when I was absent from the lab. Based on the regular emergence of the other individuals these three likely emerged in sequence by no later than the 6th of August.

Only one of the adult females found in the nest had evidence of ovarial development including a well-developed ovariole. The

Figure 1. A-D Nesting site of *Augochloropsis metallica fulgida*. A. Nest entrance of *A. m. fulgida* obscured by leaves. B. Nest entrance of *A. m. fulgida* with leaves removed. White powder surrounding entrance from plaster of Paris sprayed in nest. C. Cell cluster at base of entrance tunnel (marked with white plaster of Paris). Arrow points to vertical cell with pollen at bottom. D. Entire nest with vertical tunnel from surface (marked with white plaster of Paris) and space with cell cluster removed. E-H. Nesting aggregation of *Megachile mucida*. E. Trail at Fenner Nature Center with *M. mucida* nests. F. Female *M. mucida* entering nest with cut leaf held with mandibles. G. Curved trail of soil material removed during nest excavation (black arrows). H. Excavated nest of *M. mucida* showing depth from surface and partially exposed cells.

other had slender ovaries, but these were still more developed than newly emerged females. Both adults in the nest had evidence of wear, but there was substantially more wear to both the mandibles and wings of the female with undeveloped ovaries.

Megachile (Xanthosarus) mucida

Megachile mucida has been taken from the following locations in Michigan: ***Berrien Co.***: 5 km E of Paw Paw Lake, 29 Jul. 2011 (1 ♀ MSUC); ***Clinton Co.***: Sleepy Hollow State Park, 15 Jun. 2014 (1 ♂ JBWM); ***Ingham Co.***: MSU Beal Botanical Garden, 8 Jun. 2014 (1 ♀ JBWM); MSU Horticultural Demonstration Garden, 9 Jun. 2013 (3♀ 1 ♂ JBWM), 31 May 2014 (1 ♂ JBWM), 1 Jun. 2014 (1 ♂ JBWM); MSU Radiology garden, 15 Jun. 2014 (1 ♀ JBWM), 21 Jun. 2014 (2 ♀ JBWM); Fenner Nature Center, 31 May 2014 (2 ♀ JBWM), 7 Jun. 2014 (2 ♀ JBWM), 14 Jun. 2014 (2 ♂ JBWM); ***Ionia Co.***: Clarksville Research Center, 42.8708 -85.2544, 22 Jun. 2016, *Penstemon digitalis* (2 ♀ MSUC); ***Van Buren Co.***: 25 May 2005 (2♂ MSUC); South Haven, 3 mi. S,. 12 Jun. 2006 (2 ♂ MSUC). Historical specimens identified as *M. gemula* and *M. melanophaea* in the MSUC were not found to include misidentified *M. mucida*.

On 31 May 2014, no nesting activity was observed at the site (Fig. 1E), but two female *M. mucida* were collected. When the site was revisited on 7 June 2014, the nesting aggregation was at peak activity and bees could be observed entering and exiting nests at a high frequency (Fig. 1F). The aggregation was recognizable from a distance of several meters due to the many females engaged in nest construction and cell provisioning. The nesting aggregation was approximately 7.5 m by 5 m in size and nests were commonly separated by 20–25 cm. In one case, a female *M. mucida* was observed repeatedly attempting to enter a nest occupied by another *Megachile*. The female was repelled each time by the occupant. By 14 June 2014, activity had reduced dramatically. The nesting aggregation was still recognizable by the nest entrances, but active females were no longer visible from a distance. Bees were observed leaving and returning to nests at regular intervals, but typically only 1 or 2 females were visible at one time. In the fourth week, the aggregation was almost completely unrecognizable. Nest entrances were closed and no foraging females were observed.

On 7 June 2014, females were observed dragging dirt from the nest entrance for 15–20 cm making a visible trail which typically curved perpendicular to the direction of the nest entrance in a J-shape (Fig. 1G). Females would then either quickly walk or make a short flight back to the nest entrance and repeat the excavation behavior multiple times. Nests were built at an oblique angle into sandy soil. Nest depth was typically much less than 10 cm, often only 3–4 cm below the surface (Fig. 1H). Nest entrances were approximately 8 mm in diameter. Cells were composed of a simple tunnel extending approximately 10 to 15 cm with cells built in series at the terminus (Fig. 2A) or occasionally side-by-side. Some nests had a single cell others had 3 cells in series. One excavated nest appeared to have separate groups of cells in series, but it was unclear if these represented a single nest or multiple nests built one on top of the other.

Females were observed returning to nests with leaf pieces of various sizes. Leaves were either an oval leaf as long as or longer than the female herself (Fig. 1F) or a roughly circular leaf disc. Females would spend between 1 and 2 minutes inside the nest before leaving for another leaf piece. Females were observed flying north of the aggregation on these flights towards a wooded area. Some damaged cottonwood leaves were observed north of the aggregation (Fig. 2B), but no females were ever observed cutting leaf pieces. A typical trip for a leaf piece lasted approximately 2 minutes. Each cell was a cylinder composed of overlapping oblong leaf pieces. Three pieces were required to complete the full circumference of the cell. Several overlapping layers of leaves were used, resulting in 20–30 leaf pieces. Circular leaf pieces were placed at both ends of the cell (Fig. 2C). Several layers of circular leaf discs were used to cap the cell. Prior to cell capping, the nest was provisioned with pollen and nectar. In early stages of cell provisioning, pollen appeared to be dry. In capped cells, pollen was a solid mass (Fig. 2D) presumably held together by nectar and any glandular fluids the female might secrete.

Females of the cleptoparasitic bee *Coelioxys sodalis* (Fig. 2E) were observed flying over the aggregation during the second and third weeks. On 14 June 2014, a *C. sodalis* female was observed entering a *M. mucida* nest. After approximately 1 min., the cleptoparasite emerged and was captured. The nest was then excavated and the cells retained. Attempts were made to rear the specimens in the lab allowing them to first overwinter in an unheated building, but adults never emerged. Cells were opened and mature larva were alive inside but after a year following their overwintering period, they never completed development. A bombyliid fly, identified as *Hemipenthes sinuosa* (Wiedemann), was commonly seen at the nesting aggregation (Fig. 2F), but was never directly associated with *Megachile* nests.

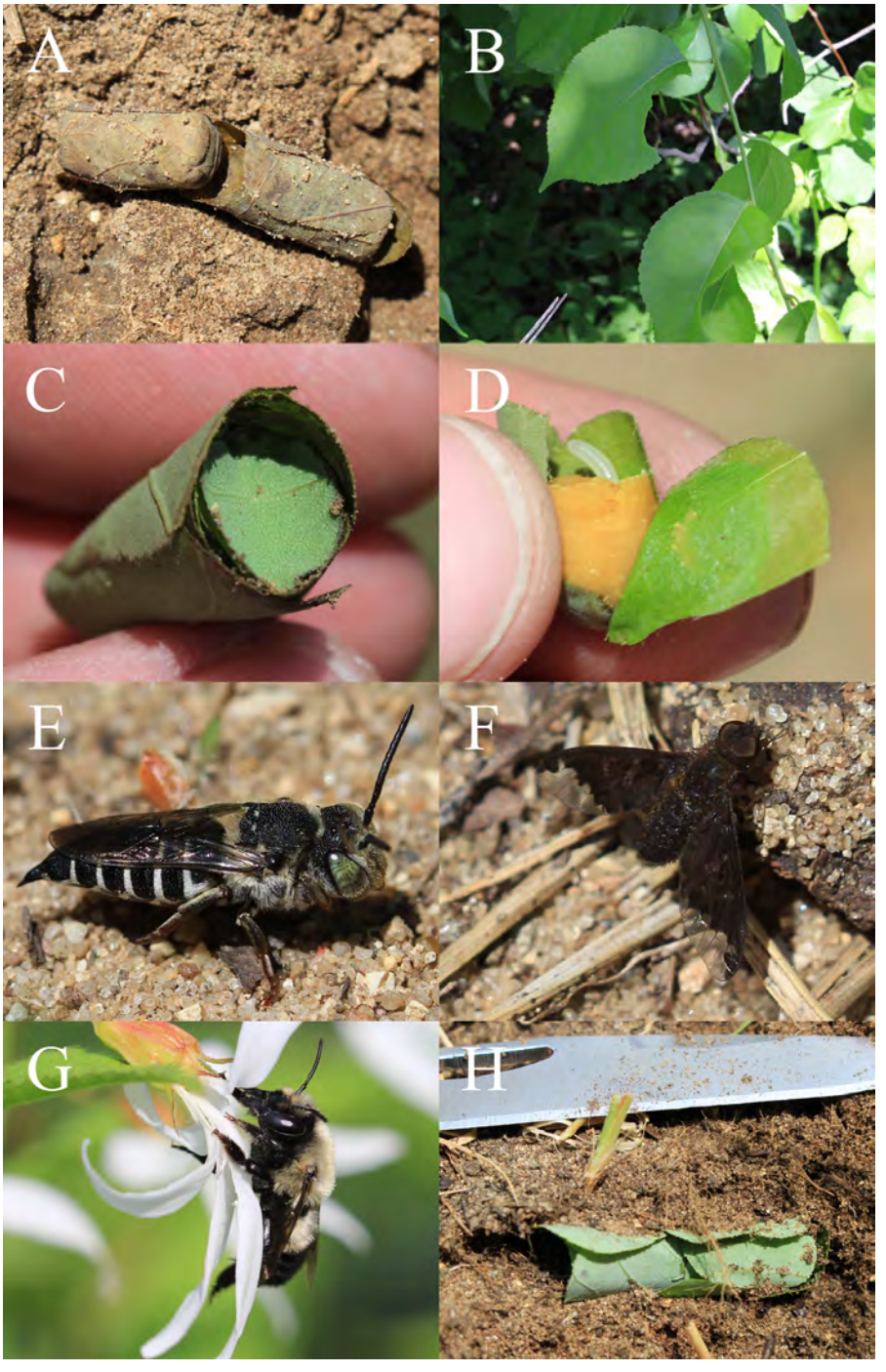

Figure 2. A-D Nesting aggregation of *Megachile mucida*. A. Two cells of *M. mucida* in series. B. Cottonwood leaves at north end of aggregation showing possible signs of *Megachile* damage. C. Complete cell of *M. mucida* showing circular leaf pieces used to close the cell. D. Opened cell of *M. mucida* showing pollen mass with attached egg. E-F. Insects associated with nesting aggregation. E. *Coelioxys sodalis* female. F. *Hemipenthes sinuosa*. G. *Megachile mucida* visiting *Gillenia trifoliata* at the Beal Botanical Garden. H. Excavated nest of *M. texana*.

In one instance, a female was observed closing a nest. She was seen pulling soil down around the nest entrance. She then flew away for approximately 1 min. before returning to continue closing the nest entrance for 30 sec. This pattern was repeated 5 times. It is unclear if these flights were normal behavior or if they were made in response to the close observation of her activity.

Males were never observed at the nesting aggregation. Males were collected patrolling at a patch of *Rubus* approximately 120 m to the south of the aggregation. No mating was observed and females were never observed on flowers near the aggregation. Males were also observed patrolling flowers on MSU campus at both the Beal Botanical Garden and Horticulture Demonstration Gardens. *Baptisia* spp. and *Gillenia trifoliata* (L.) Moench (Fig. 2G) seemed to be the preferred plant of females in the gardens.

Discussion

In *Augochloropsis m. fulgida*, the nest architecture closely matches the that of *A. (P.) iris* (Schrottky) (Michener and Lange 1959, Coelho 2002), a putatively eusocial species. The regular sequence of offspring emergence suggests that approximately one cell is provisioned every 1 or 2 days. The sex ratio of the lab-reared individuals was biased towards males, which might suggest that the excavation interrupted the construction of female cells. Only two adults were found in the nest, but the excavation occurred at approximately 2 pm, so it is possible that other foraging occupants were missed. The different levels of ovarial development observed between nest-mates of *A. m. fulgida* is strongly suggestive of division of labor. The extensive wing and mandibular wear suggest the undeveloped ovaries were not a consequence of being newly emerged. In fact, it suggests that a greater amount of nest cell construction and foraging was performed by this female (Michener et al. 1955, Ordway 1965, Packer and Knerer 1986, Mueller and Wolf-Mueller 1993). Semi-sociality, division of labor between sisters, is more commonly reported in the Augochlorini than division of labor between generations, *i.e.* eusociality (Danforth and Eickwort 1997). *Augochloropsis metallica* has been recorded as solitary or communal in some faunal studies (Wolf and Ascher 2009, Goldstein and Ascher 2016), but this may not be the case. Given the small size of the colony and the behavioral variability observed in other augochlorine species (Michener and Lange 1959, Packer 1990), it is possible that this species displays polyethism.

It is notable that *M. mucida*, a relatively distinctive species, was not collected in Michigan prior to 2005. There is a substantial bee collection at Michigan State University thanks to collectors such as Roland Fischer (MSU) and Robert Dreisbach (Dow Chemical, Midland), including material examined by a number of bee experts, most notably Theodore Mitchell, who revised the Nearctic *Megachile* (Mitchell 1935) and the bees of the eastern United States (Mitchell 1962). Given that the bee is now relatively common on the MSU campus, it seems unlikely that this species would have been missed by earlier collectors.

Another distinctive species, *Dieunomia heteropoda* (Say), was also recently recorded for the state based on specimens collected since 2003 (Gibbs et al. 2014) as were 'southern' species of *Andrena* (Tuell et al. 2009). These may be simply oversights that have been discovered recently due to increased collection effort, but it could also be that some bees with primarily southern distributions have been moving northward into Michigan in recent years. Such expansions have been speculated for other bee species (Zarrillo et al. 2016). The possibility of climate induced changes in bee distributions, the number of rare and poorly documented species, and the potential pollinator crisis make it increasingly important to document the distribution and natural history of wild bees.

Interestingly, although *M. mucida* is near the northern extreme of its range in central Michigan, its cleptoparasite *C. sodalis* is near the southern boundary of its range in the east (Baker 1975). *Coelioxys sodalis* has been previously recorded invading the nests of *M. melanophaea* (Graenicher 1927, 1935), a close relative of *M. mucida*, and also *M. texana, M. frigida* Smith (Pengelly 1955), and possibly *M. rotundata* (Fabricius) (Hobbs 1968). *Megachile texana* is a similar in size species that also has shallow underground nests (Fig. 2H) (Krombein 1953, 1970). *Megachile rotundata* is a much smaller bee that nests in cavities, but *Coelioxys* size can vary considerably intraspecifically with different host use (Packer et al. 1995). The host breadth of many cleptoparasitic bees remains poorly documented and the hosts of some species remain unknown (Baker 1975). This new association highlights another reason for additional study of bee natural history.

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Construction and Performance of a Novel Capture-Mark-Release Moth Trap

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Abstract

Mark-recapture studies can provide important information about moth movement as well as habitat preference across a landscape, but to date, such studies tend to be species-specific or require labor-intensive methodologies. To address this challenge, we designed a *capture-mark-release-trap* (CMRT) featuring a cooling unit attached to a black light trap. The CMRT captures and incapacitates moths throughout the night until the morning, when they can be marked on-site and released. Moths captured with the CMRT during summer of 2016 had a recapture rate of 1.6%, similar to those of previous studies. Importantly, because moths are immobilized by the CMRT, they can be handled and marked with ease, reducing the opportunities to damage specimens prior to release. The CMRT can capture a wide array of moth species and may facilitate an increase in the monitoring of moth movement across landscapes.

Key Words: Lepidoptera, mark-release, mark-release-recapture, insect trap, moth, cooling.

Moths are an important taxonomic group across all kinds of landscapes. As the most numerous and diverse group of Lepidoptera, they provide pollination services (MacGregor et al. 2015), break down plant biomass as immatures (Slade et al. 2013), and act as a food source to birds, bats, and other predators (Conrad et al. 2006, Bates et al. 2014). Unfortunately, many moth populations may be in decline (Conrad et al. 2006, Fox et al. 2014), potentially due to land use change (Kozlov 1996) and habitat fragmentation (Fox et al. 2014). Despite their importance, moth movement on a landscape scale has not been well explored, which can help indicate the drivers of moth population decline (Slade et al. 2013).

Exploring moth movement across a landscape can be accomplished using mark-recapture methods, where moths are marked, released and later recaptured. Comparing the biotic and abiotic properties of release and recapture locations, and the terrain in-between, can then provide information about which landscape features impede or facilitate moth movement and dispersal (Dulieu et al. 2007). This is especially important in disturbed habitats that are frequently patchy, surrounded by an unfriendly matrix (Conrad et al. 2006, Bates et al. 2014).

Mark-recapture methodologies can be broadly divided into two categories: *rear-mark-recapture* and *capture-mark-recapture*. Trapping and marking live moths can present challenges and instead, many researchers elect to rear individuals in a lab rather than catching specimens in the field (Shirai and Nakamura 1995, Margaritopoulos et al. 2012). These *rear-mark-recapture* types of studies tend to be species specific, often only focusing on the movements of one or a few key species of moths (Shirai and Nakamura 1995, Margaritopoulos et al. 2012). Though this methodology is highly effective for species-specific work, it is not practical for examining how landscape factors impact entire moth assemblages.

The alternative method, using a *capture-mark-recapture* technique, can survey a greater proportion of the local moth assemblage, but presents unique challenges of its own in obtaining live, undamaged specimens. There are a variety of popular moth traps on the market today, but none are designed specifically for *capture-mark-recapture* work. The black-light trap (BLT) is perhaps the most well-known and widely used trap. It uses low-wavelength UV or LED light to attract insects from the surrounding area (Muirhead-Thomson 1991, White et

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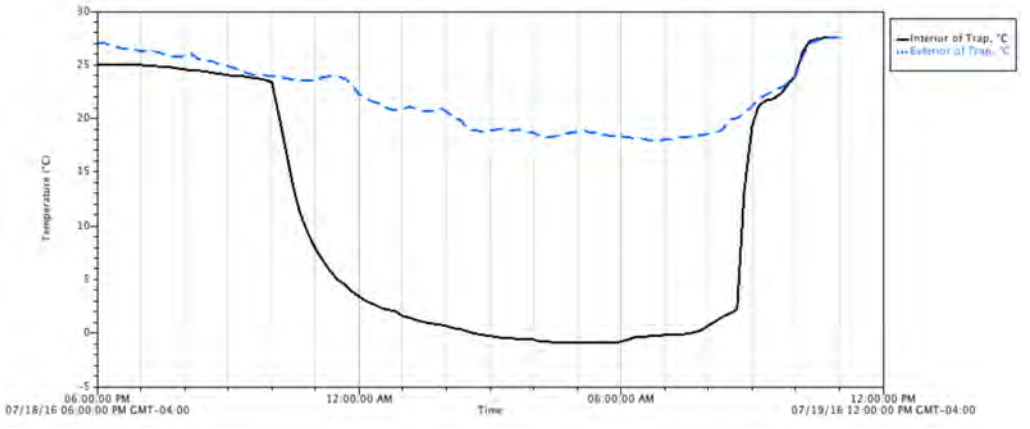


Figure 1. Internal and external temperature of a CMRT, collected with temperature sensors attached to the inside and outside of the trap (respectively).

al. 2016); it is particularly useful where researchers seek to survey an entire moth assemblage. The BLT can be used for *capture-mark-recapture* if the trap's collection container features internal structures (for example, egg-cartons) to reduce moth movement in the collection bucket, which in turn limits moth wing damage. However, this method does not sedate moths and makes moth marking a challenge. The subsequent extra handling of moth specimens can sometimes increase the incidence of moth damage.

Other popular methods in *capture-mark-recapture* studies include pheromone traps and flight intercept traps. Pheromone and bait traps use a chemical attractant rather than a light to attract moths. The chemical attractant tends to be taxonomically specific making the trap efficient for studies surveying one or a few species at a time (Furlong et al. 1995, Margaritopoulos et al. 2012), but not ideal for *capture-mark-recapture* studies that aim to survey and/or track a representative proportion of the greater moth assemblages. Finally, flight intercept traps typically involve setting up a large sheet or net and collecting anything that flies onto it. These traps often lack an attractant and have been shown to collect fewer moths and with lower species richness than BLTs (Butler et al. 1999).

There are many ways to collect moths, yet a gap exists for a trapping method designed specifically for *capture-mark-recapture* purposes at the moth community level. In this present study, we detail the construction of a novel *capture-mark-recapture* trap (the CMRT) to collect a diverse moth species assemblage in urban woodlot. The CMRT combines the efficacy of standard BLTs for attracting moths and an on-site cooling mechanism that allows the moths to be sedated with cold air over night until they are marked and released in the morning.

Methods

Trap Construction. We constructed a CMRT using the basic structure of a BLT with the addition of a cooling unit being used in the place of a standard collection bucket. The CMRT therefore consists of a light and vane structure, a cooling component, and a power source. The light and vane components are from BioQuip (parts no. 2851U and 2851A; Rancho Dominguez, CA). We modified the BLT structure by adding an adjusted portable 12V cooler (Koolatron 18 quart Compact Cooler from Amazon.com), with an opening cut in the top for the funnel to fit into, and a live collection bag (For construction details see box 1). The bulb used in a 12V BLT-type trap generally has an attraction radius of up to 30m a forest habitat (Truxa and Konrad 2012, Merckx et al. 2014).

The trap is powered using heavy-duty deep cycle 12V batteries. The batteries are kept in plastic toolboxes to protect them from rain and make transport to and from field sites easier. Both the cooler and the UV black light bulb are connected to batteries via timers so that they can be set to run at specific times during the night and early morning hours.

Study site. The CMRT was tested in the Hudson Woodlot (42° 41 58 N, 84° 28 32 N) in East Lansing, Michigan, USA. The 7.7

Table 1. Capture and recapture data. Recapture percentage is calculated as the sum total number of moths that were recaptured (*italics underlined*) divided by the total number of moths caught and dusted (**bold**).

Date	Event	# of Traps Deployed	Total # of Moths Caught and Dusted	# of Dusted Moths that were Recaptured	Total Catch Abundance for Trap Type	Recaptured Species
07/19/16	Capture	4	**276**		276	
07/21/16	Recapture	9		*1*	697	*Orthodes majuscula*
07/22/16	Recapture	9		0	427	
07/26/16	Capture	4	**238**		238	
07/27/16	Recapture	9		*2*	624	*Noctuid sp.* (x2)
07/28/16	Recapture	9		*4*	408	*Spilosoma virginica, Noctuid sp.* (x3)
07/29/16	Recapture	9		*1*	270	*Striacosta albicosta*
08/02/16	Capture	4	**149**		149	
08/03/16	Recapture	9		*2*	557	*Striacosta albicosta* (x2)
08/04/16	Recapture	9		*1*	443	*Eurois occulta*
08/05/16	Recapture	9		0	401	
08/09/16	Capture	4	**279**		279	
08/10/16	Recapture	9		*3*	643	*Xestia dolosa Orthodes majuscula, Oreta rosea*
08/11/16	Recapture	9		*1*	177	*Noctuid sp.* (x2)

ha, mixed-age woodlot is surrounded by agricultural fields south of the Michigan State University campus. The woodlot is primarily comprised of sugar maple (*Acer saccharum* Marshall), beech (*Fagus grandifolia Ehrh.*), red oak (*Quercus rubra* L.), and basswood (*Tilia americana* L.).

Trap Testing. Trapping was conducted over 4 weeks in summer 2016 from July 18 through August 11. Four CMRTs were set at the center of the woodlot, about 10 meters from one another (in a square formation) and set to run from 10:00pm at night until to 9:00am the next morning. The traps were not intended to be independent samples, rather they were clustered to increase their attracting ability. Onset HOBO pendant temperature loggers (UA-002-08; Bourne, MA) were attached to the interior and exterior of the traps to monitor temperature changes through the course of the night. The following morning, the cold-sedated moths were removed from the mesh collection bag and dusted with UV dust using a small paintbrush before being released near the capture site (Solar Color Dust brand UV sensitive dust; Winter Haven, FL). Moth captures were monitored at release sites until they dispersed.

Recaptures were collected with nine conventional BLTs, deployed for 2–3 nights throughout the woodlot, set at 50m, 100m, and 150m away from the original capture site, in each cardinal direction. Different colors of dust were used to demarcate different initial trapping events in case moths were captured later than the trapping week in which they were marked. The BLTs were equipped with pest strips containing 2,2-dichlorovinyl dimethylphosphate to kill recaptured moths; dead specimens were preferred upon recapture so that positive species identifications could be made.

Results

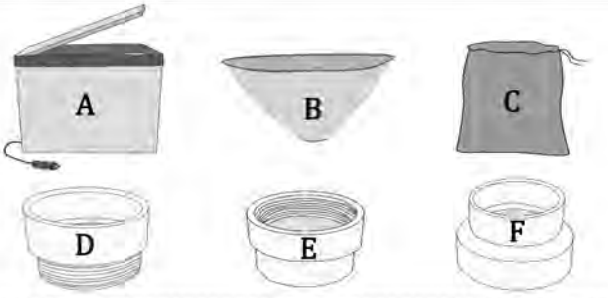
The CMRT initially captured 942 moths pooled over four capturing nights. Moths were recaptured at a rate of 1.6% (Table 1). The recaptures were in the families Noctuidate, Erebidae, and Geometridae.

The CMRT appeared to have cooled and incapacitated the moths that it captured; no moths were moving inside the collection bucket upon retrieval. After marking, it

Box 1: CMRT Construction

Parts needed for the CMRT

(A) 12V portable cooler with a top-opening lid, **(B)** funnel from a standard black light trap, **(C)** mesh insect collection bag, **(D)** 4" PVC/DWV male adapter, **(E)** 4" PVC/DWV cleanout (female) adapter, **(F)** 4" x 3" PVC/DWV reducer.



Assembly instructions for the CMRT

(A) Use window and door grade insulating foam sealant to attach the metal funnel to the 4" PVC/DWV male adapter. For a secure fit, apply foam to both the inside and outside of the adapter where it joins the funnel.

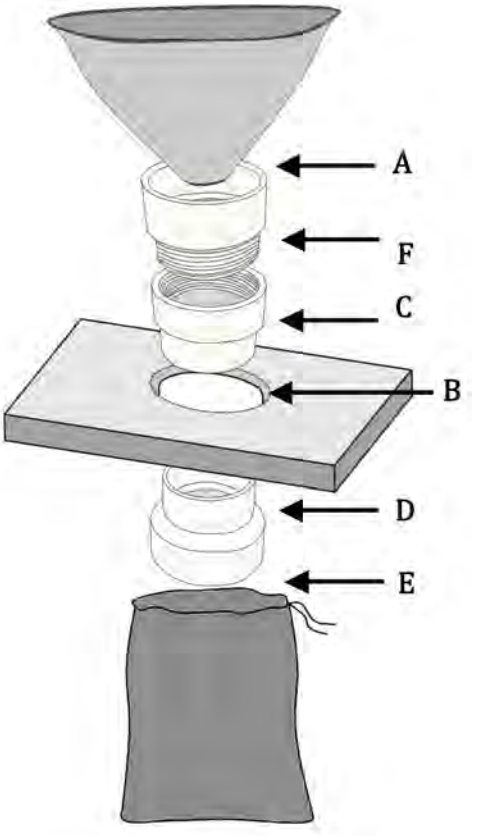
(B) Cut a 4" hole in the lid of the 12V portable cooler. This can be done by removing the lid from the cooler and using an orbital jig saw after a pilot hole has been drilled. Reattach the lid to the cooler after the hole has been cut.

(C) Use window and door grade insulating foam sealant to secure the 4" PVC/DWV cleanout (female) adapter to the cooler lid, through the newly cut hole.

(D) Use PVC cement to attach the 4" x 3" PVC/DWV reducer to the bottom of the PVC/CWV cleanout adapter. The 3" side of the reducer fits into cleanout adapter and the 4" side of the reducer opens into the cooler below.

(E) Attach an insect collecting bag to the 4" opening of the PVC/DWV reducer. The reducer provides a natural lip that the bag can be cinched around. Alternatively, an artificial lip can be made on the bottom edge of the reducer using a zip-tie or heavy-duty caulk.

(F) Screw the 4" x 3" PVC/DWV reducer (with funnel attached) into the 4" PVC/DWV cleanout (female) adapter when the trap is ready to be deployed.



A fully assembled *capture-mark-recapture* trap (CMRT).

typically it took 10–15 minutes for moths to warm up and fly away after the marking treatment was applied.

The interior of CMRTs was approximately 19°C cooler than the surrounding environment (Figure 1), effectively making the trapped individuals too cold to move. The CMRT took about 2 hours to sufficiently cool after it was turned on. Once it reached its low temperature, near 0°C, it continued running until it was turned off the following morning by the project team, prior to 9:00am.

Discussion

The CMRT may be an effective tool for moth *capture-mark-recapture* initiatives. Trapped moths are subdued by the cold temperatures inside the trap, long enough to be marked before release, and show no signs of damage upon release. The low attraction radius is ideal for studies that are monitoring a local habitat, as it is less likely the traps will catch moths from adjacent habitats.

The 1.6% recapture rate we observed (n=15 of 942 marked individuals) is consistent with other mark recapture research. For example, a study using 12-volt actinic light traps had a recapture rate of 3.88% (Dulieu et al. 2007). Another study using pheromone-baited traps had recapture percentages ranging from 1.3% and 2.5% for male codling moths (Judd et al. 2010). While these recapture rates may seem low, moths are highly agile making high recapture rates rare. It is unlikely that the moths were adversely affected by dusting with UV dust as previous studies have marked moths using similar dust with no reported impact on moth mortality (Cameron et al. 2002, Botero-Garcés and Isaacs 2004, Judd et al. 2010).

It should be noted, that the purpose of the CMRT is not necessarily to identify and record the types of moths present in a given habitat. Moths can be notoriously difficult to identify, and for most Lepidopterists, it would not be possible to identify all of the individuals collected by a CMRT, in short order, in the field. Typically, to identify and record the types of moths present in a habitat, a pesticide strip is added to a BLT and dead specimens are brought back to a lab for identification. Instead, the CMRT is designed for capture-mark-recapture studies. By definition, any individual that is captured, marked *but not recaptured*, cannot be included as part of a capture-mark-recapture dataset. Therefore, identifying *all* of the moths present at the initial capture event in the CMRT is not necessary for its intended application. That said, a high-resolution camera could be used to take photos of CMRT captures, prior to re-release should this kind of data be desired.

We caution that the effects of long term effect of cooling of moths has not been explored and could vary from species-to-species, family-to-family, and from one geographic extent to another. For example, species that are bivoltine, or with a flight season that includes cold summer or fall nights, could be more cold tolerant than species with short mid-summer flight seasons. Furthermore, assemblages in northern temperate regions may be more cold tolerant than assemblages in southern or tropical regions. Prior to using this kind of trap for a mark-recapture study, we recommend that the post-cooling survivorship of moths from a given research landscape be explored. This would involve capturing moths with the cooling trap, releasing them in a controlled environment (e.g., a rearing cage) and observing post-cooling mortality rates. The cooling mechanism on the trap can then be easily modulated, using a timer, to turn the trap on-and-off at appropriate intervals to maintain the desired temperature inside the trap.

This CMRT combined with a simple marking method that is easy to carry out in the field simplifies *capture-mark-recapture* studies and may avoid some of the challenges involved with other trapping methods. There is no need to move captured moths from the site in order to incapacitate and mark them, which decreases the risk of moth damage or mixing of samples while they are handled. The non-specific nature of the CMRT-BLT combination allows a diverse assemblage of moths to be monitored. Given the increased interest in monitoring movement of moth assemblages, the CMRT has a wide array of applications.

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Recent Siphonaptera Host and Distribution Records from Northern Michigan

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Abstract

Along with colleagues and students I collected fleas from mammals during the period 1998-2007 in five Upper Peninsula counties, and three northern Lower Peninsula counties. Also included here are a few fleas from Grand Traverse County that were mistakenly omitted from earlier publications. Identified specimens were compared to existing distribution records for both parasite and host. Only newly documented distributions for the county or the state of Michigan are listed here. One parasite record is NEW FOR MICHIGAN: *Nearctopsylla genalis genalis* (Baker) from the Least Weasel *Mustela nivalis* L. Three parasite records are NEW FOR THE UPPER PENINSULA. In addition, 15 new county host/parasite combinations are recorded from the Upper Peninsula, and 8 new county host/parasite combinations are recorded from the northern Lower Peninsula.

Seven previous studies document flea and host species distributions in Michigan's Upper Peninsula, northern Lower Peninsula and northern islands of the Great Lakes (Lawrence et al. 1965; Wilson and Johnson 1971; Scharf and Stewart 1980; Scharf et al. 1990; Scharf 1991, 1998; Scharf and Lederle 1998). Additional comparisons were made with Timm (1975) for northern Minnesota and Benton (1980) for the northeastern United States. Despite the semblance of thorough coverage by previous studies, much of the large geographic area of northern Michigan and a number of flea hosts remain unexamined. The goal of this paper is to further the knowledge of flea and host species distributions with new records from the region.

Materials and Methods

I collected or received from collaborators 100 fleas of 13 flea species from 16 mammal host species. All new host records and county records are described here. Mammals were either live trapped in Sherman live traps and released, legally harvested during furbearer trapping, or, in the case of bats, captured in mist nets permitted to Philip Myers at the University of Michigan Biological Station. A few small mammals were found as road-kills.

Locations for trapping are as follows: Cheyboygan Co.—bats 45°33′33″N-84°40′32″W; Chippewa Co.—large carnivores 46°24′56″N- 84°22′06″W; weasels, 46°24′26″N-84°24′26″; rodents and shrews 46°25′40″N-84°30′04″W; Delta Co.—rodents 45°56′30″N—86°38′20″W; Grand Traverse Co. fox, 44°53′34″N-84°30′28″W; rodents, 44°38′28″N-85°32′07″W to 44°41′55″N-85°37′16″W; Kalkaska Co. rodents, 44°48′36″N85°17′05″W. There are no lat/long locations available for collecting sites in Houghton and Keewenaw Counties.

Mammalian hosts were brushed and examined, and fleas were picked up with forceps or an alcohol wetted finger. All fleas were stored in 70% ethyl alcohol, and later mounted in Canada balsam on glass slides for microscopic examination. Most Siphonaptera were identified with the use of Holland (1949 and 1985), but Benton (1983) was useful for comparisons. Holland's nomenclature is followed except that *Nearctopsylla genalis genalis* (Baker) follows the accepted nomenclature of Hopkins and Rothschild (1953). Slides from this study and previous studies are deposited in the University of Minnesota Entomology Collection. Mammal names are according to Wilson and Reeder (2005).

Results

The following list by parasite family and species consists minimally of new county records for the parasite on the host listed. New records for Michigan, the Upper Peninsula or the northern Lower Peninsula are noted. Additional specimens that were reported in earlier works are not repeated. Following each county name is the distribution of the sexes of the fleas and collection

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dates to indicate phenology and temporal abundance.

VERMIPSYLLIDAE Wagner

***Chaetopsylla lotoris* (Stewart)** – Coyote, *Canis latrans* Say, 1 male, 1 female, Chippewa Co., 16 November 2002 NEW UPPER PENINSULA RECORD; American Marten, *Martes americana* (Turton), 2 females, Chippewa Co. 10 December 2003; Raccoon, *Procyon lotor* (L.), Chippewa Co., 15 October 2000. NEW UPPER PENINSULA RECORD

HYSTRICHOPSYLLIDAE Tiraboschi

***Ctenophthalmus pseudagyrtes* Baker -** Eastern Chipmunk, *Tamias striatus* (L.), 1 male, 2 females, Grand Traverse Co., 18 May 1987.

***Corrodopsylla curvata curvata* (Rothschild)** – Northern Short-tailed Shrew, *Blarina brevicauda* (Say), Chippewa Co. 1 male 8 September 2000.

***Doratopsylla blarinae* C. Fox –** Cinereus Shrew, *Sorex cinereus* Kerr. Chippewa Co., 1 female, 27 October 2000.

***Nearctopsylla genalis genalis* (Baker)**—American Marten, *Martes americana*, Chippewa, 5 males, 5 females, 6 December 2003; Chippewa Co., 2 males 3 female 10 December 2003. Ermine, *Mustela erminea* L., Chippewa Co.,1 male, 3 females, 2 December 2003. Least Weasel, *Mustela nivalis* L., Grand Traverse Co., 2 males, 28 December 2003. NEW STATE RECORD. Cinereus Shrew, *Sorex cinereus*, Chippewa Co., 1 male 28 July 2000, 8 October 2003, 1 female, 1 male, 11 October 2000, 1 male, 27 October 2000, 1 female, 3 females, 29 October 2000.

CERATOPHYLLIDAE Dampf

***Monopsyllus vison* (Baker)** – Eastern Gray Squirrel, *Sciurus carolinensis* Gmelin, Chippewa Co., 1 male, 2 females, 17 August 1998.

***Oropsylla arctomys* (Baker) -** Red Fox, *Vulpes vulpes* (L.), Chippewa Co., 1 female, 4 November 2000. NEW Upper Peninsula Record.

***Opisodasys pseudarctomys* (Baker) –** Southern Flying Squirrel, *Glaucomys volans* (L.), Chippewa Co., 1 female, 31 August 1998.

***Orchopeas caedens* (Jordan) –** Eastern Chipmunk, *Tamias striatus*, Grand Traverse Co., 1 female, 18 May 1987.

***Orchopeas howardi* (Baker)-** American Marten, *Martes americana* , Chippewa Co., 1 male, 2 females, 10 December 2003.

***Orchopeas leucopus* (Baker) -** White-footed Deer Mouse *Peromyscus leucopus* (Rafinesque), Cheboygan Co., 4 females, 9 July 2000; 2 females, 2 August 2000, Grand Traverse Co., 4 females, 16 July 2007, Grand Traverse Co.,2 males, 2 females 25 July 2007; North American Deer Mouse, *Peromyscus maniculatus gracilis* Le Conte, Delta Co., 2 males, 11 females, 29 July, 2000, Chippewa Co, 5 females, 25 August 2000; Red Fox, *Vulpes vulpes*, Grand Traverse Co. 1 female, 13 February 1988, Meadow Jumping Mouse, *Zapus hudsonius,* (Zimmerman), Grand Traverse Co., 1 female 24 July 2007.

***Peromyscopsylla hesperomys* (Baker) –** White-footed Deer Mouse *Peromyscus leucopus* 1 male, Grand Traverse Co. 16 July 2007, Cheboygan Co.; 1 female, 9 July 2000.

ISCHNOPSYLLIDAE Wahlgren

***Myodopsylla insignis* (Rothschild)** – Little Brown Myotis *Myotis lucifugus* (Le Conte), Cheboygan Co., 7 males, 11 females 31 July 2000.

Discussion

Collections of one or a few fleas indicate a single host was examined. Capture records of larger scale trapping include: the Boardman River Small Mammal Survey in Hess and Scharf (2007), three vials of bat fleas indicating as many bats from Cheboygan Co., and four vials of mouse fleas from Delta Co. from Philip Myers. Weasel captures are enumerated below.

Nearctopsylla genalis genalis is the most common flea found on *Mustela erminea* Miller (2004, unpublished) captured a total of 32 weasels, 9 Long-tailed Weasels (*Mustela frenata* Lichtenstein) and *23* Short-tailed Weasels (*M. erminea).* Of the 11 species of fleas he found on both weasel species, 57.5% were *N. genalis genalis.* The rest of the fleas collected by Miller were ascribed to stragglers from the weasel's prey. They were unavailable for this study. Miller gave me specimens of the emine fleas. Fleas from two other mustelids (American Marten, *Martes americana* and Least Weasel, *M. nivalis*) indicate that *N. genalis genalis* is probably a true parasite of mustelids. Shrews of the genus *Sorex* also regularly harbor this flea.

Orchopeas leucopus is a generalized parasite of mice that has been found on a large variety of hosts including transfer to many mouse predators (Lawrence et al. 1965; Wilson and Johnson 1971; Scharf and Stewart 1980; Scharf et al. 1990; Scharf

1991, 1998; Scharf and Lederle 1998). I found it to be the only flea (with two exceptions of *Peromyscopsylla hesperomys*) on the newly immigrant White-footed Mouse (*Peromyscus leucopus*) from southern Michigan which has replaced the North American White-footed Deer Mouse (*Peromyscus maniculatus gracilis*) in much of the northern lower and upper peninsulas due to climate change (Myers et al. 2005, Myers et al. 2009). The close association between *O. leucopus* and the White-footed Mouse was also shown by Mize et al. (2011). They report that of 98 fleas from 164 *P. leucopus* trapped in southern Michigan 96 were *O. leucopus*. By contrast, *P. m. gracilis* has at least five species of flea commonly found on it (Scharf 1991).

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Effect of Habitat on Blow Fly (Diptera: Calliphoridae) Oviposition in Michigan

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Abstract

Forensic entomology applies data gained from insects to aid the criminal justice system. Blow flies (Diptera: Calliphoridae) are usually the first insects to arrive and oviposit (lay eggs) on carrion. Their quick appearance is the foundation for post mortem interval estimations, making any factors that influence their oviposition crucial. This study examined the effects of habitat (forest vs. prairie) on blow fly oviposition timing. Research was conducted in 2015 at Pierce Cedar Creek Institute in Barry County, Michigan. No significant differences were found in oviposition timing or frequency between prairie and forest habitats. Temperature and humidity were not correlated with oviposition timing, which contradicted previous studies. *Lucilia coeruleiviridis* (Macquart) was the dominant species found, comprising about 90% of collected specimens. The data confirm previous reports that *Lucilia* species are the first to arrive on carrion.

Keywords: Forensic Entomology, Prairie, Forest

Forensic entomology is the use of insects in the criminal justice system (Greenberg 1991, Amendt et al. 2007, Haskell and Williams 2008, Byrd and Castner 2009). Colonization by blow flies (Diptera: Calliphoridae) usually occurs within the first few hours after death and is used to estimate the postmortem interval (PMI) (Haskell and Williams 2008). The PMI is the period of time between death and corpse discovery. Establishing estimations of the PMI is an important contribution of forensic entomology to investigators. A number of different factors can influence blow fly oviposition (egg laying) such as weather (Mann et al. 1990), temperature (Ames and Turner 2003), chemicals (Goff 1993), and habitat (Matuszewski et al. 2013, Silahuddin et al. 2015).

This study examined the relationship between habitat and oviposition timing. Previous studies have reported differences in decomposition rates of blow fly breeding in different habitats (Cruickshank and Wall 2002, Vanin et al. 2008, Matuszewski et al. 2013, Silahuddin et al. 2015). Silahuddin et al. (2015) documented differences in decomposition rates between jungle, highland, and rural areas, with rural areas having the fastest rate of decomposition. Matuszewski et al. (2013) found *Lucilia sericata* (Meigen) bred exclusively in open habitats and Sarcophagidae species regularly bred in open habitats and rarely in forest habitats in Central Europe. A study done in England by Cruickshank and Wall (2002) found that *Lucilia* species were caught in warmer, more humid field sites. They also found that in the absence of odors, *L. sericata* aggregated near the hedgerow at the edges of farm fields. Vanin et al. (2008) studied *L. sericata* in northern Italy and found that the species does not show a habitat preference in rural regions with urban sprawl.

There is an absence of published data on blow fly habitat preferences in the United States (with the exception being rural vs urban studies), and this research provides data on the first blow flies to arrive in forest and prairie habitats in Michigan. Based on the results of previous studies (Cruickshank and Wall 2002, Matuszewski et al. 2013, and Silahuddin et al. 2015) the authors hypothesized that oviposition would occur faster in the prairie habitat than the forest habitat. Typically researchers use one dedicated field site for their studies, and it is possible that different habitats will have different oviposition times. It is important to understand the potential effects of the habitat where field trials are conducted, in order for the trials to be applicable in other situations.

Materials and Methods

Research was conducted from June 1 to August 10, 2015 at Pierce Cedar Creek

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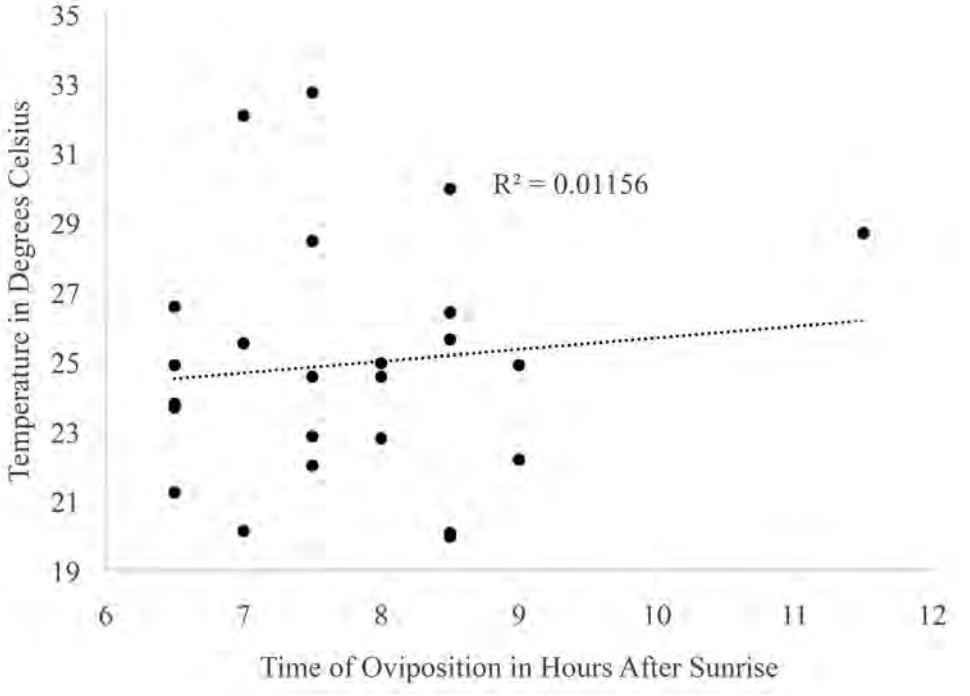

Figure 1. Ambient temperature at the time of oviposition is not correlated with the timing of oviposition in hours after sunrise (r^2=0.012, df=22, P=0.617).

Institute in Barry County, Michigan. Pierce Cedar Creek Institute is a 300 ha nature preserve that has forest, prairie, and wetland habitats, as well as two small lakes and two creeks running through the property. The Institute has a weather station on site (approximately 0.4 km from the field sites), that recorded the temperature and humidity data used in this study.

Field sites were located on three different trails at the Institute, and were chosen because of the close proximity of forest and prairie habitats to each other. Each field trial consisted of bait cups in a prairie and forest location along one of three trails. Ten bait cups were used for each field trial (n= 3 trials per trail). Cups were placed in forest (n = 5 replicate cups) and prairie (n = 5 replicate cups) habitats. Ninety bait cups total were used in the experiments (10 cups per trial × 3 replicates × 3 trails). Bait cups were used to attract blow flies for oviposition and consisted of a clear 0.47 L plastic cup with approximately 6.35 mm of vermiculite in the bottom and a foil cup with approximately 60 grams of aged (approximately 14 hours in a fume hood) chicken liver placed inside. The covered cups were placed on the ground at the sites 4 hours after sunrise, to allow the cups to acclimate to the ambient temperature. Zurawski et al. (2009) found the earliest that blow flies oviposited diurnally was three hours after sunrise, with an average of 5.6 hours after sunrise. Using the Zurawski et al. (2009) data to inform bait placement, trials began six hours after sunrise. The lids were removed from the cups and observations began. Every half hour the cups were checked for blow fly eggs, flesh fly larvae, adult flies and other insects. Once oviposition or larviposition was observed, the cup was covered, labeled, and removed from the field. Observations ended 12 hours after sunrise. Bait cups with eggs or larvae were placed in the fume hood and reared to the third larval instar stage and identified to species for Calliphoridae and family for Sarcophagidae (Stojanovich et al. 1962, Whitworth 2006).

Analysis: Data were analyzed using SPSS statistical software (SPSS 2009). Independent sample t-tests were used to examine significant differences in the number and timing of oviposition events for prairie and forest observation trials. The trails were also tested individually using independent sample t-tests. A one way ANOVA compared oviposition timing on the three trails. Separate correlations examined the relationship

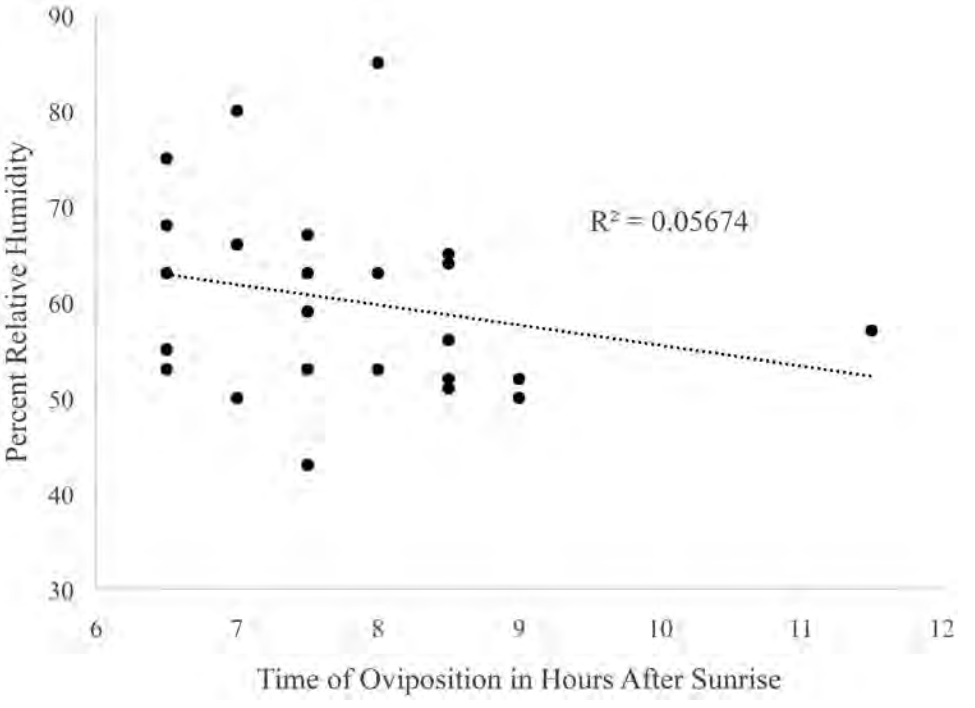

Figure 2. Humidity at the time of oviposition is not correlated with the timing of oviposition in hours after sunrise (r^2=0.057, df=22, P=0.262).

between the timing of oviposition and temperature (Fig. 1), and humidity (Fig. 2).

Results

A total of 6,267 maggots were identified from nine trials. *Lucilia coeruleiviridis* (Macquart) was the dominant species found, comprising around 90% of all collected specimens. Table 1 contains specific species information for all trials.

There was no significant difference (significance level P = 0.05) in oviposition timing between habitats when all combined prairie sites were compared to all combined forest sites, (t = –0.196, df = 84, P = 0.845). The three different trails were tested independently and all results showed no significant difference in oviposition timing (trail one: t = –0.143, df = 28, P = 0.888; trail two: t = .389, df = 24, P = 0.701; trail three: t = –0.736, df = 28, P = 0.468). A one way ANOVA and tukey posts hoc tests showed no significant difference in oviposition timing between any of the prairie and forest sites on the three trails (F = 1.24, df = 85 , P = 0.298).

Abiotic factors were examined for significant relationships to oviposition timing. There were no significant correlations between temperature and time of oviposition (r^2 = 0.012, df = 22, P = 0.617) (Fig. 1) or humidity and time of oviposition (r^2 = 0.057, df = 22, P = 0.262) (Fig. 2).

Discussion

This study had species composition results that were consistent with previous findings by Gruner et al. (2007) in Florida. Gruner et al. (2007) found *L. coeruleiviridis* to be the most abundant calliphorid species collected, comprising about 90% of the species collected on days 1–2 of the study in the summer. They reported that *L. coeruleiviridis* was always the first to arrive at the fresh carrion and the first to deposit eggs (Gruner et al. 2007). This is similar to results found at Pierce Cedar Creek Institute, where *L. coeruleiviridis* represented about 90% of species collected (Table 1), and were the first blow flies recorded ovipositing. Joy et al. (2006) also reported *L. coeruleiviridis* as the initial colonizers of carcasses in Virginia.

Lucilia species are known to be early arrivers at carrion and therefore important in forensic entomology investigations (Byrd and Castner 2009, Joy et al. 2006). However, they are not always the dominant species found in succession studies. Previous work by Haskell (1989) was done in Northwest

Table 1. Species composition for three trail locations. A total of 6,267 larva were identified from 9 trials. Data from the three replications at each field site are compiled.

	L. coeruleiviridis	*L. sericata*	*P. regina*	Sarcophagidae
Trail 1 Forest	97%	0	0	3%
Trail 1 Prairie	91%	0	0	9%
Trail 2 Forest	100%	0	0	0
Trail 2 Prairie	100%	0	0	0
Trail 3 Forest	90%	10%	0	0
Trail 3 Prairie	97%	0	0.80%	2.20%

Indiana, which has a similar climate and is geographically close to Pierce Cedar Creek Institute. He found that in the summer *Phormia regina* (Meigen) comprised 85% of the total specimens with the *Lucilia* species represented at 10% and *Cochliomyia macellaria* (Fabricius) 5% in Northwest Indiana. This is vastly different from the data found in this study, where *Lucilia* species dominated. It has been documented that *Lucilia* species will be the first to colonize and dominate species collections early, then their numbers will decline and *P. regina* or other species will become dominant (Joy et al. 2006). The Haskell (1989) study spanned multiple days, where the current study took place over six hours, which could account for the difference in overall species composition between the studies. Future work could document the difference in species composition over an extended time period in prairie and forest habitats.

The results of this study were similar to those found by Matuszewski et al. (2013) in terms of the habitat that Sarcophagidae were found. Our study found Sarcophagidae most often in the prairie habitat, and only in small numbers in one of the forest sites (Table 1). Matuszewski et al. (2013) also found Sarcophagidae most commonly in open habitats and only rarely in forest habitats. However, they found that *Lucilia* species only bred in open habitats, and our study found them in high numbers in all of the field sites (Table 1).

The prairie sites in the study were characterized by open fields and grasses (direct sunlight), as opposed to the forest sites that contained dense trees and shaded canopies. Previous studies by Joy et al. (2006) and Sharanowski et al. (2008) found conflicting results when they examined sunlight vs shaded habitats. Joy et al. (2006) found no difference in oviposition timing for carrion in the shade, versus direct sunlight, in West Virginia in the spring and fall. They did find that decomposition occurred faster in the direct sun habitats. They attributed this to temperature differences between the habitats. They also found that *L. sericata* dominated the species composition in the early days of the experiment, and there was not a difference in species composition between sunlight and shaded habitats. In contrast, Sharanowski et al. (2008) noted a greater species diversity in sunlit habitats when compared to shaded ones in Saskatchewan. The Pierce Cedar Creek study did not find a difference in species abundance or composition between habitats. The results of this study indicate that research trials conducted in prairie or forest habitats would be applicable for either habitat in reference to oviposition timing.

The researchers thought that oviposition timing would be tied to ambient weather conditions, since there appeared to be a shift towards earlier oviposition in the warmer month of July. In June oviposition tended to occur later in the day, specifically between 7.5 to 12 hours post sunrise. At the end of July, oviposition occurred between 6 and 9.5 hours after sunrise. When the temperature and humidity at the time of oviposition were plotted against oviposition timing, there were no significant correlations (Fig 1, 2). This is surprising, because blow flies are more active at warmer temperatures. Zurawski et al. (2009) found that blow flies became active earlier in the day and oviposited earlier in warmer temperatures. Therefore, researchers hypothesized that oviposition would occur earlier in the day when the temperature was higher. The data do not support this hypothesis, as there was not even a small correlation between the ambient temperature and time of oviposition ($P = 0.617$).

No significant differences were found in the timing of oviposition between prairie and forest sites, but this research provides three important pieces of information regarding blow fly oviposition timing. (1) Oviposition timing is critical to postmortem interval estimations, and this study found oviposition occurring the most frequently at 7.5 hours after sunrise. (2) Research conducted in prairie or forest settings should be applicable to either habitat, as long as other factors such as temperature are consistent.

(3) Temperature and humidity were not correlated with oviposition timing, contradicting previous studies that blow flies are more active at warmer temperatures (Joy et al. 2006, Zurawski et al. 2009). Future research should continue to examine factors that affect the timing of blow fly oviposition.

Acknowledgments

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Confirmed Presence of the Ambush Bug *Phymata vicina vicina* (Heteroptera: Reduviidae: Phymatinae) in Michigan

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Thirty-two species of Reduviidae, in 20 genera, were previously known from Michigan (McPherson 1992, Swanson 2013). Of that diversity, the subfamily known as ambush bugs constitutes only a small portion. Recently, I provided a synopsis of the two species found in the state (i.e., Swanson 2013), while noting the potential presence of a single additional species, *Phymata vicina vicina* Handlirsch, 1897. In support of my prediction, a specimen of *P. v. vicina* was discovered among undetermined material during a visit to the C. A. Triplehorn Insect Collection of The Ohio State University (OSUC). The specimen (Fig. 1) bears the following label data: **MICHIGAN**: Macomb Co., Richmond, 25 June 1969, Brivio, det. D. R. Swanson 2016, OSUC_651131 [1 male]. The specimen was collected in the southern part of the Lower Peninsula, which is unsurprising given the species' presence in adjacent Midwest states and the collecting bias for this region of Michigan. However, based on other state and provincial records in North America, latitude alone likely does not exclude this species from the northern extremes of Michigan, and it remains to be seen how widely this species is distributed in the state. Its unreported status appears to be attributable to lower abundance than other native ambush bugs, as *P. v. vicina* is relatively easy to distinguish from congeners.

This species is known from Alberta, Arizona, British Columbia, Colorado, Connecticut, Florida, Illinois, Indiana, Kansas, Manitoba, Massachusetts, Nebraska, New Jersey, New York, Pennsylvania, Rhode Island, Saskatchewan, South Dakota, Texas, Utah, and Virginia, as well as Washington, D.C. (Froeschner 1988, Maw et al. 2000). Additionally, records of *P. vicina* from California, Missouri, and North Carolina are archived in the Heteroptera Species Pages of the Plant Bug Planetary Biodiversity Inventory (Schuh 2017), although the subspecific identities of these specimens are potentially confounded with *Phymata vicina parvula* Kormilev, 1957, known from Texas (Froeschner 1988). Blatchley (1926), Evans (1931), and Kormilev (1957, 1960) each contributed additional information about this species.

In Michigan, *P. v. vicina* is easily distinguished from all other congeners by its small size and distinctly toothed connexival margin (Fig. 1). The latter character is similar to that of *Phymata fasciata fasciata* (Gray 1832), although *P. f. fasciata*, despite not being limited to the Gulf States, appears to be latitudinally-excluded from Michigan (Swanson, unpublished). My previous key to species (i.e., Swanson 2013) should be amended by inserting the following couplet at the beginning of the key:

0 Size small, length 5–6.5 mm; second through fourth connexival segments strongly toothed, fifth and sixth strongly salient [Fig. 1]; scutellum with linear or sublinear carina, lateral branches absent or obsolet.....*Phymata v. vicina*

0' Size larger, length usually greater than 7 mm; connexival margin essentially smooth, if toothed, then inconspicuously so; scutellum with cruciform carina, lateral branches well-developed.....1

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Figure 1. *Phymata vicina vicina*, adult male, dorsal habitus. Scale bar = 1 mm.

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First Record of *Hippodamia variegata* (Coleoptera: Coccinellidae) in Illinois, U.S.A., and Relation to Its Other Midwestern Collection Records

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Abstract

Hippodamia variegata (Goeze) (Coleoptera: Coccinellidae) is an Afro-Eurasian lady beetle first discovered in North America near Montreal, Canada, in 1984. Subsequent records have occurred over a gradually expanding area radiating from the initial detection site and also include a disjunct record from British Columbia. Here, we report the first Illinois specimen of *H. variegata*, collected in 2004, and discuss this in relation to previous reports of *H. variegata* in North America.

Hippodamia variegata (Goeze) (Coleoptera: Coccinellidae) is an Afro-Eurasian lady beetle first discovered in North America near Montreal, Canada, in 1984 (Gordon 1987). Subsequent collections have been made over a gradually expanding area radiating from the initial detection site (Wheeler 1993, Wheeler and Stoops 1996, Ellis et al. 1999). In recent years, *H. variegata* has expanded into mid-continental North America (Gardiner and Parsons 2005, Pavuk et al. 2007, Gardiner et al. 2009, Williams and Young 2009, Heidel and Morey 2011), and it now extends to South Dakota, North Dakota and Manitoba (Hesler and Lundgren 2011, Semmler and Wrigley 2015). A disjunct population of *H. variegata* exists in British Columbia, Canada (Klimaszewski et al. 2015).

During routine insect collection maintenance at the USDA-ARS North Central Agricultural Research Laboratory (NCARL), Brookings, South Dakota, we discovered an unsorted specimen of *H. variegata* collected from Illinois in 2004. Here, we present its collection information and briefly discuss the record in relation to previously published reports of *H. variegata* in North America.

New state record. ILLINOIS. Champaign County, Champaign, University of Illinois, Cruse Research Farm, 40.092° N, -88.242° W, 24-IV-2004, J. G. Lundgren, 1 adult female. The specimen was collected in a pitfall trap, and its identity was determined to species using the description in Gordon and Vandenberg (1991). The specimen is housed at the NCARL.

Hippodamia variegata was collected at the Illinois site as part of a study that sampled predatory beetles (Lundgren et al. 2006). Other agrobiont lady beetle species were also sampled from this site, but this was the only specimen of *H. variegata*. The collection of *H. variegata* in an agricultural setting is consistent with many of its previous collection records in North America (Ellis et al. 1999, Gardiner and Parsons 2005, Day and Tatman 2006, Pavuk et al. 2007, Heidel and Morey 2011, Hesler and Lundgren 2011).

This finding prompted us to search for additional records of *H. variegata* from Illinois in the Severin-McDaniel Insect Research Collection (SMIRC), South Dakota State University; the insect collection at the NCARL; and the Symbiota Collections of Arthropods Network database (SCAN 2017), which houses specimen occurrence records and images from more than 80 North American arthropod collections, including ones in and around Illinois. No records of *H. variegata* earlier than 2012 were found for the Midwestern U.S.A., and no additional Illinois record of it was found.

The Illinois specimen represents the earliest record of *H. variegata* from the Midwestern U.S.A. and predates the first records of *H. variegata* from nearby states to the east (Michigan in 2005, Gardiner and Parsons 2005; Ohio in 2007, Pavuk et al. 2007) and north (Wisconsin in 2005, Williams and Young 2009). Records of *H. variegata* west

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of Illinois do not occur before 2009 (Heidel and Morey 2011, Hesler and Lundgren 2011).

Thus, the Illinois record of *H. variegata* reported herein begs the question of how it pre-dates records from Midwestern states further east. Possible explanations include the chance detection of this individual from an established, but initially low-density population of *H. variegata* in Illinois. *Hippodamia variegata* might have been established, but not yet detected, in Ohio when the Illinois specimen was collected in 2004. Alternatively, the record could represent fortuitous collection of an individual *H. variegata* in Illinois that had leapfrogged adjacent states to the north and east. It is unlikely that this individual stemmed from releases of *H. variegata* in states west of Illinois from 1987 to 1994 because there is no evidence of establishment following those releases (Prokrym et al. 1998, Ellis et al. 1999). The reporting of any additional survey and collection data for *H. variegata* in Illinois and adjacent states is encouraged to develop context for this record and to improve our understanding of this species' dispersal in central North America.

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